

REPORT



FLOW EVALUATION REPORT AMENDED MARCH 2010

**CITY OF HAMPTON
DEPARTMENT OF PUBLIC WORKS
WASTEWATER OPERATIONS DIVISION
550 N. BACK RIVER ROAD
HAMPTON, VIRGINIA**

March 15, 2010



TABLE OF CONTENTS

Executive Summary For Amended Flow Evaluation Report	i
1.0 Introduction	1
1.1 Scope.....	1
1.2 Background.....	1
2.0 Flow and Rainfall Monitoring Methodology & Approach.....	3
2.1 Use of Existing Data	3
2.2 Monitoring Site Selection	3
2.3 Monitoring Equipment Used.....	6
2.4 Data Collection Activities.....	13
2.5 QA/QC Procedures	14
2.6 Procedures for Translating Monitored Basin Information to Unmonitored Basins	14
3.0 Monitored Flow Characterization and Assessment.....	19
3.1 Data Analysis Overview	19
3.2 Dry Weather Flow Reliability Analysis.....	19
3.3 Water Usage for Base Flow Development.....	25
3.4 Dry Weather Infiltration Analysis	27
3.5 Dry Weather Flow Analysis.....	28
3.6 Typical Dry Weather Diurnal Pattern	29
3.7 Wet Weather Flow and Rainfall Analysis	30
3.8 Hydrologic Model Calibration and Model Parameters	48
3.9 Peak Flow Estimation and Peak Flow Threshold Determination	58
3.10 SSES Basin Determination Based on Peak Flow Threshold Analysis	60
4.0 Findings and Conclusions	64
4.1 Discussions of Findings	64
4.2 Electronic Media Data	64
4.3 SSES Basin Results from Peak Flow Analysis.....	65
4.4 Future Hydrologic Model Calibration Efforts	65

Appendices

Appendix A Large Maps

Appendix B DDF Curves for Rainfall Events

Appendix C Gravity Flow Meter Installation Reports

Appendix D Gravity Flow Meter Maintenance Reports

Appendix E Gravity Flow Data and Dry Weather Diurnal Flow Patterns

Appendix F Stage-Storage Analysis Graphs and Corrected Inflow Hydrographs

Appendix G Wet Weather Hydrographs and Simulation Statistics

Appendix H SCADA High Wet Well Alarm Records

Appendix I Data Disk

LIST OF FIGURES

Figure 1.1 Hampton Sanitary Sewer System.....	2
Figure 2.1: Flow Meter Locations	4
Figure 2.2: Proposed RTS-Compliant Flow Meter Locations.....	5
Figure 2.3: RTS-Compliant Rain Gauge Locations	8
Figure 2.4: Radar-Supplemented Rain Gauge Locations	10
Figure 2.5: Final Rain Gauge Coverage of City.....	11
Figure 3.1: DWI Calculation as 80% of Minimum Dry Flow	26
Figure 3.2: Example Diurnal Patterns – PS 142 and 126	29
Figure 3.3: Basin Associations	42
Figure 3.4: RTS-Compliant Monitored Areas	43
Figure 3.5: RTS-Compliant and Non-RTS-Compliant Monitored Areas	44
Figure 3.6: Flow Meter Locations with Compliance.....	45

LIST OF TABLES

Table 2.1: Flow Monitoring Plan Monitoring Sites	3
Table 2.2: Flow Monitoring Sites Installed for RTS Compliance	4
Table 2.3: Flow Monitoring Sites with Non-RTS-Compliant Data	5
Table 2.4: Rain Gauge Data Source per Storm Event	9
Table 2.5: Rain Gauges & Associated Service Areas	12
Table 2.6: Association Procedure.....	16
Table 2.7: Original Flow Monitoring Locations and Basin Associations	16
Table 3.1: Summary of Flow Monitoring Sites and Sewered Areas	19
Table 3.2: Summary of Dry Weather Flow Monitoring Sites Reliability Analysis	20
Table 3.3: Summary of Additional Dry Weather Flow Monitoring Sites Reliability Analysis	22
Table 3.4: Summary of Non-RTS-Compliant Flow Monitoring Sites	23
Table 3.5: Service Area Associations after Dry Weather Analysis.....	25
Table 3.6: Dry Weather Flow Parameter Summary	28
Table 3.7: Storm Events and Rainfall Depths in Inches.....	30
Table 3.8: Summary of Wet Weather Flow Monitoring Sites Reliability Analysis.....	32
Table 3.9: Meter Sites with Tail Water Conditions.....	37
Table 3.10: Final Service Area Associations.....	41
Table 3.11: Observed Wet Weather Flows at Monitoring Locations.....	46
Table 3.12: RDII Volume Comparison	47
Table 3.13: Dry and Wet Weather Flow Parameters for All Basins	50
Table 3.14: 10-Year Peak Flow Estimates	59
Table 3.15: Peak Flow Analysis for SSES Basin Determination	60

EXECUTIVE SUMMARY FOR AMENDED FLOW EVALUATION REPORT

This amended report supersedes the report dated May 26, 2009 and the response to DEQ general comments dated December 4, 2009 and submitted on January 8, 2010.

Updated responses to DEQ comments dated December 4, 2009 are included in this Executive Summary.

Responses to DEQ comments dated January 8, 2010 are included in this Executive Summary.

UPDATED RESPONSES TO DEQ COMMENTS DATED DECEMBER 4, 2009

- 1.) RTS Section 3.3.4 discusses flow monitoring data reliability in relation to monthly monitoring periods and during qualifying rain events. Please submit a table(s) addressing the raw data reliability percentage (% reliable) of each metered location on a monthly basis (for each month during the flow monitoring period) and for each of the 3 minimum qualifying rain events. In addition provide rainfall dates, total rainfall depth, and rainfall recurrence interval for those events. Ensure this information is provided for all rain events used for SSES determination or for model flow parameter development.

Response: These tables have been provided in Sections 3.2 and 3.7 and any revision to the flow monitoring data has been presented.

- 2.) If surcharging occurred at any of the metered locations during flow monitoring, provide the percentage (%) of the data subject to surcharged conditions. Include this information in the same table(s) if possible. Provide a discussion on the technical approach used to estimate inflow during surcharged conditions and if this data was considered reliable in the percentages presented.

Response: Both surcharging and flows impacted by tail water conditions have been presented in Sections 3.2 and 3.7. A stage-storage method approach has been used to estimate inflow during surcharged and tail water conditions existing at locations where data was considered reliable in the percentages presented.

- 3.) Provide a discussion addressing current or planned flow monitoring activities, as applicable. Address if any flow monitoring has been continued, has been initiated or is anticipated since the submittal of the FER. Specify these flow monitoring locations and flow monitoring methods. Identify if these areas were previously flow monitored or previously unmonitored. Discuss if this flow monitoring is short term or long term.

Response: Additional flow monitoring was conducted in 2009. A detailed description is provided in Section 3.

UPDATED RESPONSES TO DEQ COMMENTS DATED JANUARY 8, 2010

Hampton FER dated May 26, 2009
Comments: 1/8/10

Listed after each FER comment below, a location of where the response to the comment can be found in this Amended Flow Evaluation Report

-
1. Per RTS Section 3.4.2, provide complete meter installation reports with details including a site sketch and or photos of the meter location and piping configurations. It appears some locations were missing (i.e. 147-PS and 162-PS). **This information has been noted in Section 2.3, and the detailed information is provided in Appendix C.**
 2. Per RTS Section 3.3.5, provide discussion of the rain gauge data in the FER. Discuss if the 17 rain gauges installed remained operable, were continuous recording type, stored data in 15 minute increments at 0.1-inch intervals or less during the flow monitoring period. Discuss if supplemental rain data was purchased. Also discuss any calibration and re-calibration efforts. **As discussed at our February 19, 2010 meeting, the city has supplemented its rainfall data with calibrated radar data. This is discussed in detail in Section 2.3 with Figures 2.3, 2.4, and 2.5 showing the coverage of the city.**
 3. Per RTS Section 3.3.1, provide a map showing all pump station service areas. On the map, identify service areas with RTS compliant flow monitoring. Also identify associated basins. Methodology for associating basins needs to be consistent with the Flow Monitoring Plan and with the SSES Plan. **Additional maps have been added. Figure 2.2 shows the locations of the proposed RTS-Compliance meters. Figures 3.4 and 3.5 show the service areas with RTS-Compliant flow monitoring and non-RTS-Compliant monitoring. A table and map showing service area associations are included as Table 3.10 and Figure 3.3. The methodology for association of basins is discussed in Section 2.6 and matches the current SSES Plan on file with DEQ.**
 4. Provide additional discussion and classification details describing the categories or methods used for service area association as presented in the FER. Areas can only be associated with areas having RTS compliant flow monitoring methods. Areas selected for flow monitoring shall be selected so that the entire area of interest can be characterized (RTS Section 3.3.1). **This discussion is provided in Section 2.6 and supplemented with Fig. 3.3.**
 5. Per RTS Section 3.3.2, Confirm that each open channel flow gravity meter was equipped with a data logger and communication device meeting RTS minimum requirements. **This confirmation is provided in Section 2.3.**
 6. Per RTS Section 3.3.2, discuss the ability of the gravity meters to record both low flow and surcharged conditions and methods to calculate true inflow rates. **The ability of the gravity meters to record low flow and surcharged data is discussed in Section 2.3. A stage/storage method for calculating true inflow rates during surcharged and tail water conditions has been utilized. A detailed discussion is provided in Section 3.7.**
 7. Per RTS Section 3.3.3, confirm and provide discussion in the FER that a minimum of 20% of Hampton's pump station service areas were monitored with RTS compliant flow monitoring methods and met minimum data accuracy collection specifications in RTS Section 3.3.4 and minimum data reliability requirements. Discuss the ability of the appropriately monitored locations to represent Hampton's entire sewer service area. **Section 3.7 contains the data and discussion confirming that 24 of the city's 104 pump station service areas were monitored with RTS compliant flow monitoring methods. Section 3 contains the map showing the locations of the city's RTS compliant meter sites.**
 - a. Note that RTS Section 3.3.3 states that additional monitoring beyond 20% shall be conducted as necessary to accurately characterize flows for either SSES identification

and/or hydraulic model calibration. **A discussion of where the city has performed additional flow monitoring for hydraulic model calibration only is provided in Section 2.2.**

8. Per RTS Section 3.5.1.4, provide the RDII volume or %RDII observed in conjunction with each qualifying rain event used for model parameter development or SSES determination at each monitored location. **This information has been provided in Table 3.12 in Section 3.7.**
9. As referenced in RTS Section 3.4.2, provide a tabulation of daily average, maximum, minimum and peak hour flow rate recorded during the flow monitoring period for each flow monitored location. **Table 3.11 has been provided in Section 3.7.**
10. Discuss the significance of the scatter plots for each gravity meter specifically in reference to the rain events to be used for model verification and calibration. **The use of scatter plots of meter data is discussed in Section 2. Scatter plots of the rain events are provided in Appendix G.**
11. Discuss and provide records of meter/gauge calibration and recalibration events during the flow monitoring period. **This discussion is provided in Section 2.4, and the records of meter/gauge calibrations and recalibrations are provided in Appendix D.**
12. Discuss in the FER the ADF analysis indicating if it excluded days with rainfall and the following 3 days. **This discussion is provided in Section 3.5.**
13. Provide the analysis of DWI using the water consumption data and monitored ADF for comparison to the use of 80% of ADF for DWI determination. FER Page 13 indicates that the RTS allows the use of 80% of ADF to equal DWI. Provide the RTS Section reference. **A detailed explanation of the use of water consumption data for Base Flow Development is provided in Section 3.3.**
14. Discuss the determination of ADF in basins without RTS compliant flow monitoring data. **This discussion has been provided in Section 2.6**
15. Provide the methodology and data analysis for each service area without reliable RTS compliant flow monitoring data. This should be based on the data from the associated/representative area. **This discussion has been provided in Section 2.6.**
16. Provide a table showing all the RTK parameters, DWI and BSF parameters developed for each basin (monitored and non-monitored/associated). Also indicate the data source as monitored per RTS standards and the method, as applicable or representative/associated. (FER Table 3.5) **This Table 3.13 has been provided in Section 3.8.**
17. Per RTS Section 3.5.1.4, provide the peak hour flow observed at each RTS compliant flow monitoring site with reliable data in conjunction with each qualifying rainfall event. **This Table 3.11 has been provided in Section 3.7.**
18. Provide discussion, calculations and results for the 10 year projected flow for each service area (not just flow monitored areas) and comparison to the peak flow threshold. **This discussion has been provided in Section 3.10 and Table 3.15.**

-
19. RTS Section 3.4.2 requires that flow summaries be included in the Flow Evaluation Report to include graphical and tabular presentation of flow data in the context of rain events.
- Provide tabular data specific for each flow metering method (i.e. open channel flow meters: time, flow depth, velocity and flow rate) per monitored location. This can be described in the FER, an example provided and the complete raw data set provided electronically for each monitored location.
 - Graphically, provide a minimum of 3 inflow hydrographs per monitored location depicting qualifying wet weather events with reliable data sets (including at least 1 event with at a 1 year rainfall recurrence interval). On each wet weather hydrograph show the observed flow data, modeled flow data, modeled ADF hydrograph, rainfall data, describe the rainfall recurrence interval, indicate the peak flow threshold, and indicate the projected 10 year peak flow for reference.
 - Note the events where high wet well levels, surcharging or high wet well alarms occurred.

This information has been provided in Appendices E, G, and H and Table 3.8 as well as provided on the Data Disk.

20. In the FER provide a discussion and summary of the information contained in each folder on the electronic media submitted. **This information has been provided in Section 4.2**
21. Discuss if locations, identified in the Flow Monitoring Plan (and subsequently modified in Table 2.4) as the selected RTS compliant flow monitoring locations that have not captured reliable data (excluding data impacted by surcharging as necessary) for the minimum qualifying events, are continuing to monitor and/or have adjusted the monitoring location in order to collect the appropriate data needed to satisfy the requirements of the RTS. **This amended FER demonstrates that the City of Hampton performed RTS compliant flow monitoring during the original flow monitoring period that ended at the end of September 2008.**
22. Please note that in accordance with RTS Section 6.5, minimum calibration and verification requirements are discussed that pertain to the data collected during the flow monitoring period for both dry weather and wet weather flows. Although not required to be submitted at this time, this information will need to be submitted in support of the RHM. Ensure that adequate data has been obtained to calibrate and verify the modeling parameters to actual flow data within the accuracy limits discussed in the RTS Section 6.5. This will require the use of reliable data for more than one qualifying rain event including a minimum 1 year recurrence rain event at each monitoring location. **This information has been generated with this FER and calibration statistics are included with each RTS-Compliant monitoring site in Appendix G. This information has been included in the updated Flow Parameter Database delivered to CDM and HRSD on March 15, 2010.**

If after data QA/QC and evaluation, it is determined that the minimum amount of reliable data (excluding data impacted by surcharging as necessary) has not been obtained, additional monitoring must be initiated until the minimum RTS requirements are met. Please add discussion in the FER addressing these issues as necessary. **This amended FER demonstrates that the City of Hampton performed RTS compliant flow monitoring during the original flow monitoring period that ended at the end of September 2008.**

-
23. At flow monitored locations, model flow parameters (i.e. RTK values) for areas that did not have reliable RTS compliant flow monitoring data for the minimum qualifying rain events will need to be reevaluated after reliable RTS compliant flow monitoring data is obtained. Please add discussion in the FER addressing this issue as necessary. **RTK parameters were only developed where reliable RTS compliant flow monitoring data was collected. This has been described in Section 3.8**
24. Monitored areas that were not deemed SSES basins due to peak flow threshold exceedance and did not have reliable RTS compliant flow monitoring data for the minimum qualifying rain events will need to be reevaluated. This will also affect areas represented/associated with these areas. Please add discussion in the FER addressing this issue as necessary. **This information has been provided in Sections 3.7, 3.9, and 3.10 for RTS compliant meter sites. Section 3.10 provides the information on how the peak flow threshold analysis was applied to associated service areas to establish SSES basin status or not. Table 3.15 provides a summary of all service areas monitored and associated service areas and their SSES basin status.**
25. During the review of the Flow Evaluation Reports, it appears that the methodology for development of the 10 year peak flow by application of long term simulations or a standard rainfall distribution is not consistent among the Localities. Due to the lack of specificity on this analysis in the RTS, DEQ anticipates further discussion with the capacity team. As a result, further comments on this issue may be forthcoming. **The 10-year peak flow projection developed in this FER is following the guidelines issued in Technical Interpretation #2 which allows the use of a standard rainfall distribution method.**
26. Any changes or modifications to the data in the Flow Evaluation Report based on DEQ comments or other comments/review resulting in a modification of an SSES basin criteria will require modification and re-submittal of the SSES Plan. **As result of our February 19, 2010 meeting, the city has supplemented its rain fall data with calibrated radar data for this Amended FER. The resulting changes reported in this Amended FER will require the City of Hampton to submit an Amended SSES plan that will supersede all previous SSES plans and addendums on file with DEQ.**

Please provide a written response to all parts of each comment and submit an amended report or addendum to the FER, as necessary, within 60 calendar days from receipt of these comments.

This page intentionally left blank.

1.0 INTRODUCTION

On September 26, 2007, the Virginia Department of Environmental Quality (DEQ), State Water Control Board, issued a Special Order of Consent (SOC) to the Hampton Roads Sanitation District (HRSD), the cities of Chesapeake, Hampton, Newport News, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg; the counties of Gloucester, Isle of Wight, and York; the James City Service Authority; and the town of Smithfield for the purpose of resolving certain alleged violations of environmental laws and regulations. The purpose of the SOC and its associated Regional Technical Standards (RTS) was to reduce the occurrence of sanitary sewer overflows (SSOs) in the Regional Sanitary Sewer System.

This revised report supersedes the report delivered on May 26, 2009.

1.1 Scope

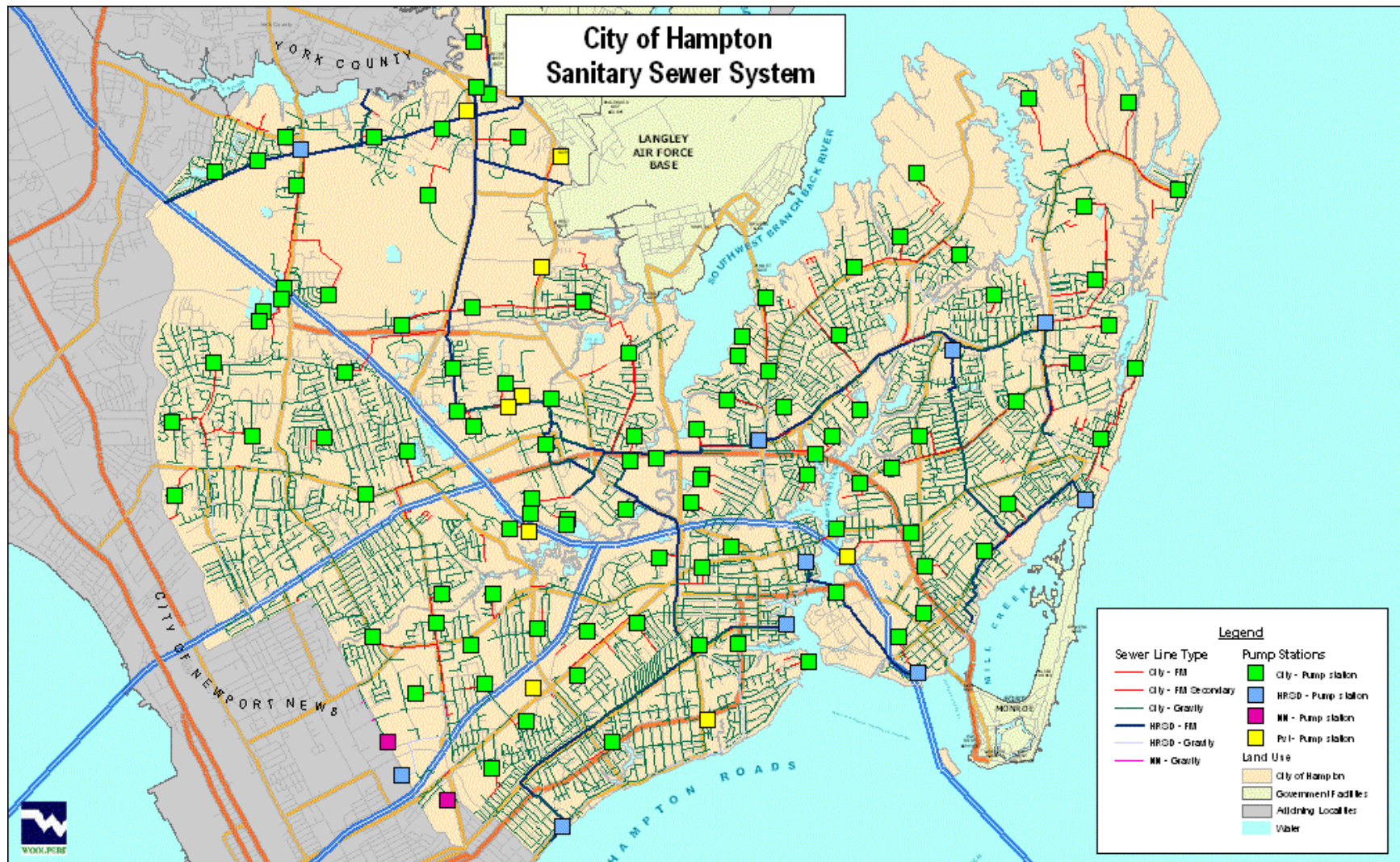
To comply with the terms of the Regional SOC and the RTS, the City of Hampton is required to perform the following task:

Flow Evaluation Report: A summary report shall be prepared documenting the: 1) flow monitoring activities performed; 2) flow monitoring data collected; 3) flow analyses conducted; 4) findings; and 5) conclusions. These flow evaluation reports shall be used to determine SSES basins and to prepare the SSES Plan for the sewer system.

1.2 Background

There are 104 pump stations in the City of Hampton due to the flat topography found in coastal Virginia. The City of Hampton Department of Public Works provides sanitary sewer collection services to 145,000 people via 46,000 accounts across approximately 136 square miles. The City owns more than 430 miles of gravity pipelines, ranging in size from 4 inches to 21 inches in diameter; approximately 11,055 access structures; 104 pump stations, 5 of which are for individual facilities and do not have service areas; and approximately 47 miles of force mains. All sewage collected is pumped to HRSD for treatment. The City of Hampton's sewer system is depicted in Figure 1.1 on the following page. (Large copies of the maps in this report can be found in Appendix A.)

Figure 1.1 Hampton Sanitary Sewer System



2.0 FLOW AND RAINFALL MONITORING METHODOLOGY & APPROACH

2.1 Use of Existing Data

In December 2007, the City of Hampton submitted a Flow Monitoring Plan (FMP) to the Virginia Department of Environmental Quality. The data collected as a result of this plan was used to prepare the SSES plan and this document.

2.2 Monitoring Site Selection

According to the FMP, monitoring sites were identified based upon the following criteria:

1. Sites that already have permanent meters installed (installed as a part of the previous Consent Order requirements)
2. Stations that are scheduled to have permanent meters installed where capacity related SSOs have occurred and auxiliary pumping is typical
3. Sites where capacity related SSOs have occurred and auxiliary pumping is typical that were not scheduled for permanent meters and portable flow meters can be installed
4. Sites that will use other monitoring methods to determine flow

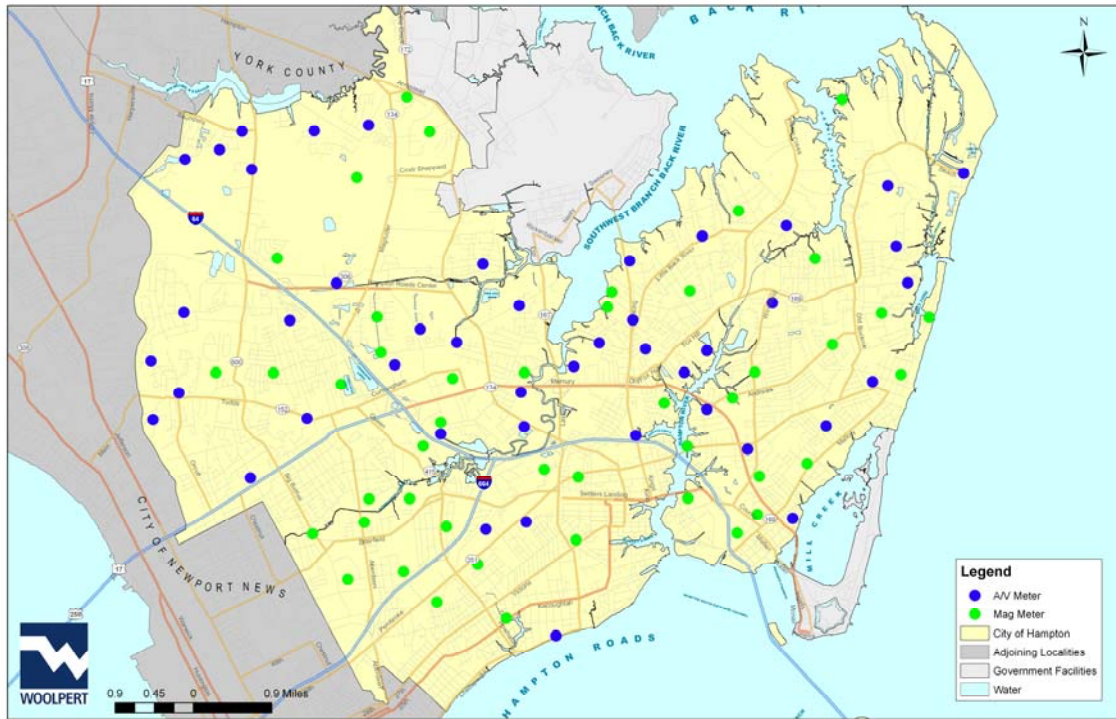
The specific sites were depicted in the mapping sections of the FMP and are listed in Table 2.1 below:

Table 2.1: Flow Monitoring Plan Monitoring Sites

Meter Type	Number of Planned Locations	Meter Locations (Pump Station Service Areas #)
Existing Permanent Meters	46	001, 003, 004, 005, 006, 007, 011, 013, 014, 016, 017, 027, 030, 031, 032, 033, 034, 036, 041, 043, 100, 101, 102, 103, 104, 105, 106, 107, 111, 112, 113, 114, 115, 116, 117, 123, 124, 127, 131, 132, 133, 134, 135, 137, 141, 153
New Permanent Meters	6	042, 048, 140, 146, 151, 154
Temporary Portable Meters	28	010, 012, 015, 020, 021, 022, 023, 024, 026, 035, 037, 044, 047, 051, 098, 118, 122, 125, 126, 130, 136, 142, 143, 145, 147, 159, 162, 170
Other Monitoring Methods	12	002, 025, 028, 038, 045, 046, 121, 144, 148, 150, 152, 163
Excluded from Plan	11	009, 018, 019, 108, 160, 161, 164, 165, 166, 167, 168
Not listed in Plan *	1	119
	104	

* Station 119 is a new station for Hampton. It was not listed in the Flow Monitoring Plan because it was previously served by HRSD station 222 and the Hampton station came online after the FMP was created.

Figure 2.1: Flow Meter Locations

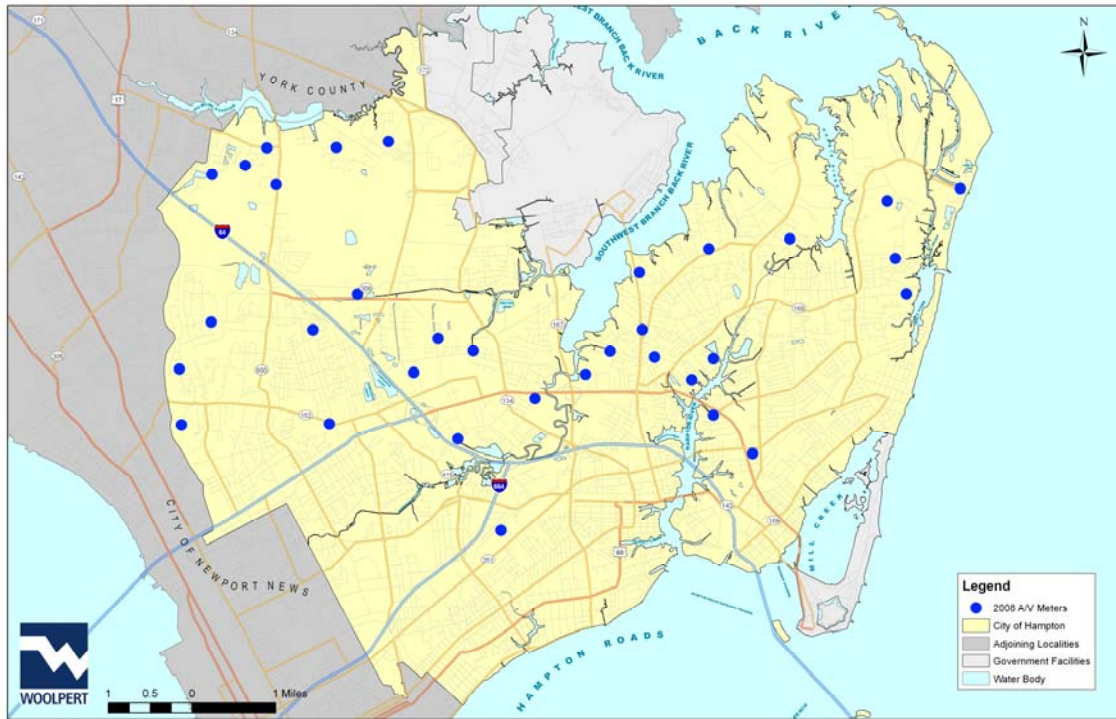


The actual locations of the RTS-Compliant meters varied from the original FMP because of service area limitations and data collection methods. The temporary Area-Velocity meters were installed in March 2008 and removed in October 2008. Data from these meters was used to develop the SSES Plan and start the modeling efforts. The locations of proposed RTS-compliant meters and the areas that they serve are listed in Table 2.2 below. Figure 2.2 shows the locations of these sites with in the city limits.

Table 2.2: Flow Monitoring Sites Installed for RTS Compliance

Meter Type	Number of Locations	Meter Locations (Pump Station Service Areas)
Temporary Portable Meters	33	010, 012, 015, 021, 022, 023, 024, 026, 035, 037, 042, 044, 047, 048, 051, 098, 118, 121, 125, 126, 130, 136, 140, 142, 143, 145, 146, 147, 151, 154, 159, 162, 170

Figure 2.2: Proposed RTS-Compliant Flow Meter Locations



Data from non-RTS-compliant meters is only valid for dry-weather flows but was collected and analyzed to assist with hydraulic model calibration per RTS section 3.3.3. The permanent meters record the daily total volume of flow. The temporary Area-Velocity meters are of the same type as the RTS-compliant meters, but these sites were installed from March 2009 to July 2009 and were only intended to supplement the RTS-compliant data and provide information on dry weather flows in areas around the city. All non-compliant locations were associated to compliant meters for their wet-weather analysis. No unmonitored basins were associated to these non-compliant meters. While these locations are not RTS-compliant, they provide more accurate dry weather flow information than values developed through association. Dry Weather information from these meters will be used with the locality hydraulic model and the Regional Hydraulic Model being developed by HRSD. The locations of the non-RTS-Compliant meters are listed in Table 2.3 below.

Table 2.3: Flow Monitoring Sites with Non-RTS-Compliant Data

Meter Type	Number of Locations	Meter Locations (Pump Station Service Areas)
Permanent Meters	46	001, 003, 004, 005, 006, 007, 011, 013, 014, 016, 017, 027, 030, 031, 032, 033, 034, 036, 041, 043, 100, 102, 103, 104, 105, 106, 107, 111, 112, 113, 114, 115, 116, 117, 119, 123, 124, 127, 131, 132, 133, 134, 135, 137, 141, 153
Temporary Portable Meters	12	City Pump Stations: 011, 106, 119, 133, 134 Manholes within HRSD Service Areas: 203-282, 208-191, 219-140, 219-214, 223H-121, 224-145, 225-168

2.3 Monitoring Equipment Used

According to the FMP, there are five types of equipment being used as part of the plan:

- Permanent Mounted Flow Meters
- Open channel flow meters (portable, temporary)
- Rain Gauges
- SCADA (Supervisory Control and Data Acquisition Units)
- Telog Units for Data Management

Permanent Meters

Hampton has several types of permanent mounted flow meters in use. These meters are not RTS-Compliant.

- In Line Magmeters (Hersey, ISCO, Adv Flow and Taylor)
- Direct Buried Magmeters (Taylor and Adv Flow)
- UniMag (Adv Flow)

A magnetic flow meter (magmeter) is a volumetric flow meter which does not have any moving parts and is ideal for wastewater applications. Magmeters feature low pressure drop across the meter and are low maintenance. The operation of a magmeter is based upon Faraday's Law, which states that the voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor. In the case of in line magnetic flowmeters, a magnetic field is established throughout the entire cross-section of the pipe. With insertion-style flowmeters, the magnetic field radiates outward from the inserted probe.

Magmeters typically require a minimum of ten pipe diameters of straight run upstream and five diameters downstream. Magnetic flow sensors are sensitive to electrical noise which is present in most piping systems. In plastic piping systems, the fluid carries significant levels of static electricity that must be grounded for best magmeter performance. Magmeters are very sensitive to air bubbles. The sensor cannot distinguish entrained air from wastewater causing the magmeter to read high. This is normally not a problem in wastewater force mains near the pump station but may be further away.

Temporary Meters

The temporary flow measurements were recorded using Isco 2150 series open channel area-velocity meters. These meters consist of a submerged sensor installed in the sewer mainline to measure both level and velocity and a meter unit which is typically hung on the steps in a manhole. The sensor unit is mounted to a metal ring and the ring then slipped into an incoming pipe of a manhole selected for flow metering so that the sensor rests at the invert of the pipe. If silt or other debris is present in the pipe, the sensor may be rotated so that is clear of the foreign matter and an adjustment is made in the meter programming to account for this offset. The meter unit contains a data logger with flash memory to store the collected data, two 6 volt batteries as a power source, and a cellular modem (communications device) that allows for remote data retrieval. This meter configuration meets the RTS section 3.3.2 requirements.

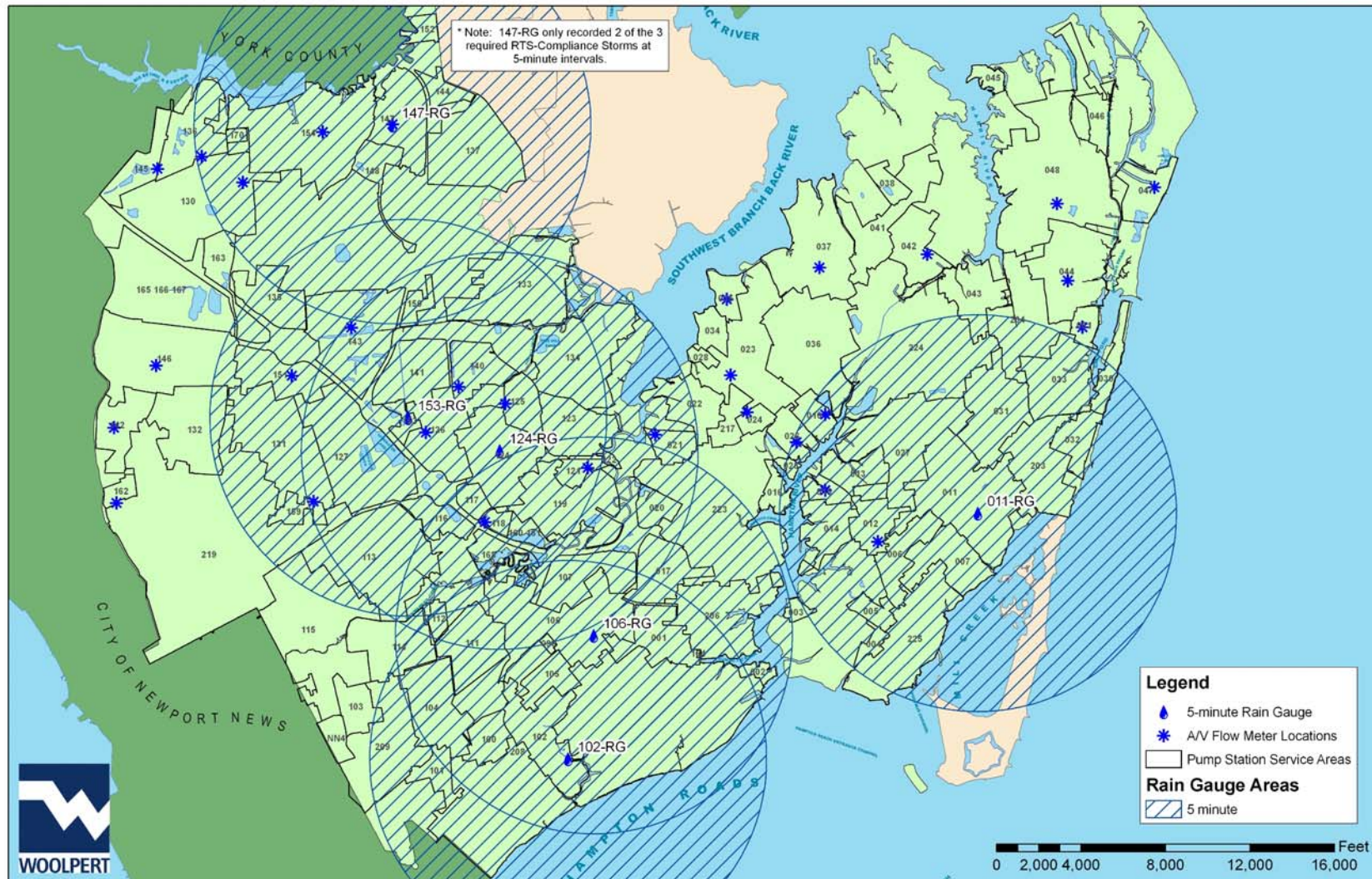


The level is measured using a differential pressure sensor that calculates the depth by comparing the pressure of the flow at the sensor to the ambient atmospheric pressure measured by a port on the meter case. The mean velocity is measured by transmitting an ultrasonic signal into the flow and recording the frequency shift of returned signal reflected by particles and air bubbles in the flow. Both of these readings were collected at five minute intervals. Using the pipe diameter measured by the installation crew, the flow was then calculated by the meter using the continuity equation by multiplying the flow area by the mean velocity. These temporary meters are capable of recording low flows and are also capable of recording flows during surcharged conditions. Meter installation sheets for these area-velocity meters are included in Appendix C. A sample of recorded data is shown in Appendix E, and the full dataset is included on the provided Data Disk.

Rain Gauges

The rain gauges in use are manufactured by NovaLynx Corporation and have tipping bucket style mechanisms. All gauges are of the continuous recording type and record at 0.01 inch increments. The original May 26, 2009 Flow Evaluation Report focused on 17 locations. This has since been updated. There are 17 rain gauges across the city of Hampton's sewer service area that have available data during the flow monitoring period. 11 of them only record daily totals. 6 sites recorded daily totals until July 2008 when they were connected to the Telog system. This allowed them to record in 5-minute intervals per RTS requirements. The RTS-compliant locations are shown in Figure 2.3 below. The circles around each gauge inscribe 10 square miles of area. 5 of these gauges recorded all 3 required RTS storm events during the period that they were recording in 5-minute intervals. However, 147-RG only recorded one 1" event and one 1-yr event during this time. Its dataset was supplemented by radar data for the April 21, 2008 rain event.

Figure 2.3: RTS-Compliant Rain Gauge Locations



Supplemental radar rainfall data was obtained from the National Oceanic Atmospheric Administration to ensure that all other rain gauge locations within the city were covered within a 10 square mile circle around a rain gauge. Radar rain data is accurate to 0.01” increments. This fills in the gaps in the city’s 5-minute rain gauge coverage as allowed in RTS Section 3.3.5. This radar data was calibrated to each rain gauge across the city to provide a 5-minute rainfall pattern for each qualifying storm. Site 145-RG was proposed in the Flow Monitoring Plan but was not installed. Since radar rainfall can be generated at any point using a city-wide calibration factor instead of a site-specific factor, rainfall data was generated at this location. The locations where this radar data is necessary to provide RTS-compliant rainfall data for qualifying storms are shown in Figure 2.4 below. Figure 2.5 shows the entire city-wide coverage obtained from RTS-compliant gauges and the radar-supplemented locations. A summary table of the Rain Gauge Data Source is provided in Table 2.4 below.

Table 2.4: Rain Gauge Data Source per Storm Event

	4/21/2008	8/10/2008	8/15/2008	9/5/2008	9/10/2008	9/25/2008
004-RG	RSD	RSD	RSD	RSD	RSD	RSD
011-RG	RSD	5-min	5-min	5-min	5-min	5-min
017-RG	Radar	Radar	Radar	Radar	RSD	RSD
023-RG	RSD	RSD	RSD	RSD	RSD	RSD
031-RG	RSD	RSD	RSD	RSD	RSD	RSD
036-RG	RSD	RSD	RSD	RSD	RSD	RSD
045-RG	RSD	RSD	RSD	RSD	RSD	RSD
047-RG	RSD	RSD	RSD	RSD	RSD	RSD
102-RG	Radar	5-min	5-min	5-min	5-min	5-min
103-RG	RSD	RSD	RSD	RSD	RSD	RSD
106-RG	RSD	5-min	5-min	5-min	5-min	5-min
124-RG	RSD	5-min	5-min	5-min	5-min	5-min
145-RG	Radar	Radar	Radar	Radar	Radar	Radar
146-RG	RSD	RSD	RSD	RSD	RSD	RSD
147-RG	RSD	5-min	5-min	5-min	5-min	5-min
153-RG	RSD	5-min	5-min	5-min	5-min	5-min
159-RG	Radar	RSD	RSD	RSD	RSD	RSD
162-RG	Radar	RSD	RSD	RSD	RSD	RSD

In the table above, “5-min” indicates that the rain gauge recorded good 5 minute data so that actual recorded dataset was used. The “RSD” items are Radar-Supplemented Daily data which is the radar rainfall calibrated to that site’s daily rainfall totals. Site 145 used the “Radar” dataset, which is the radar-generated rainfall pattern created from the calibration of the radar data to the city-wide rain gauges for a particular storm. 017-RG, 102-RG, 159-RG, and 162-RG also used this dataset for individual storms when their rain gauges were malfunctioning.

Figure 2.4: Radar-Supplemented Rain Gauge Locations

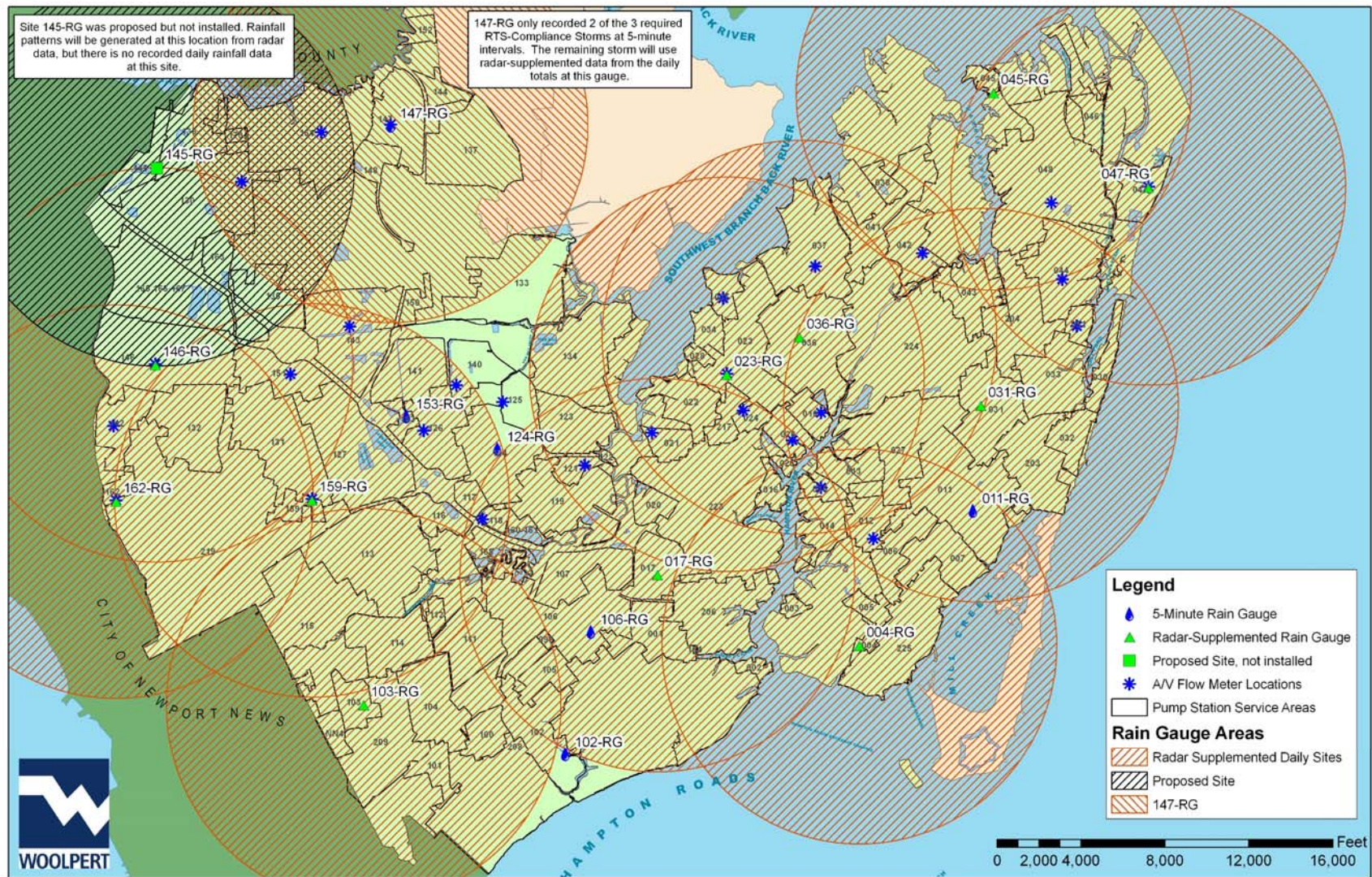
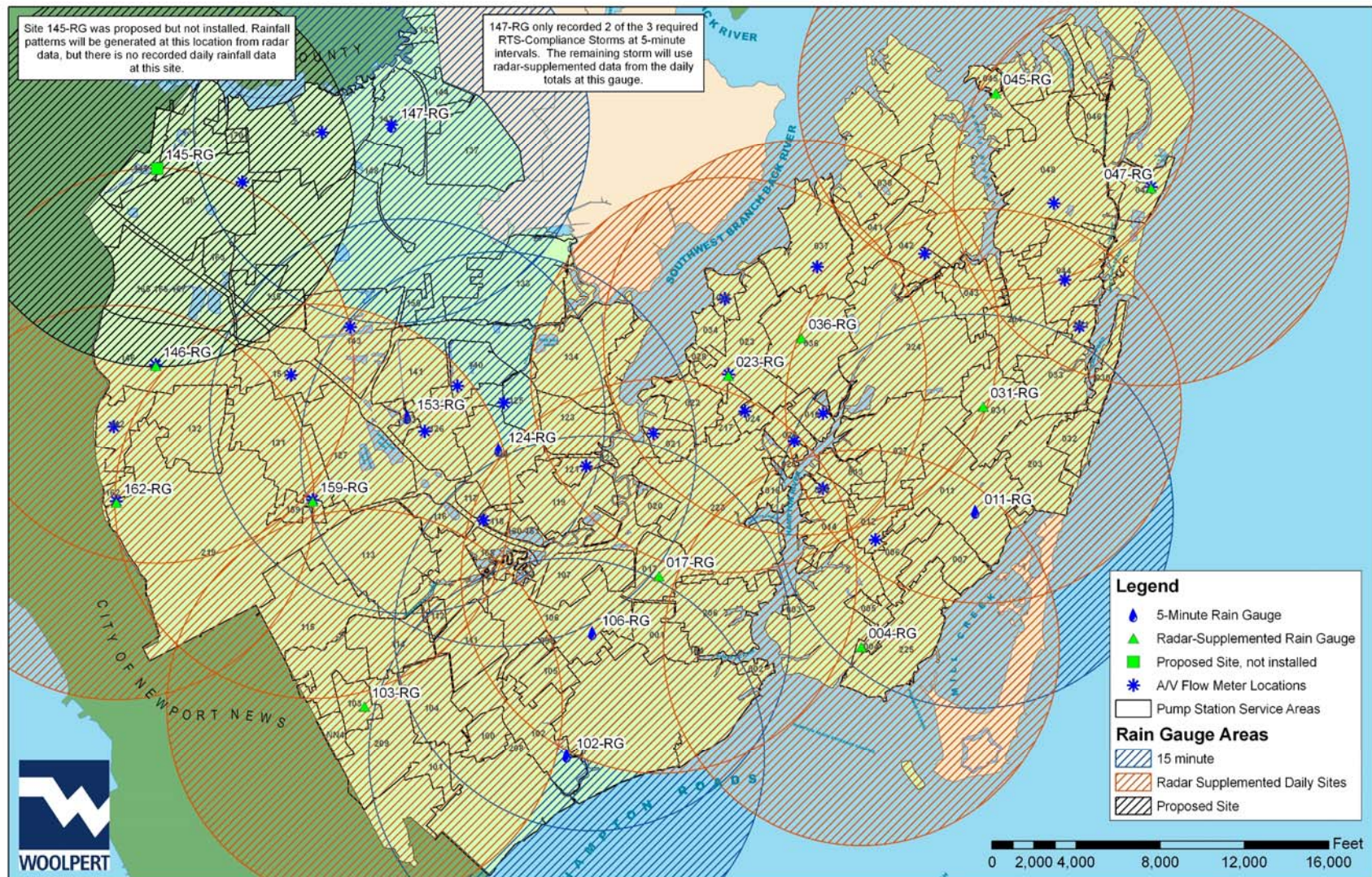


Figure 2.5: Final Rain Gauge Coverage of City



RTS section 3.3.5 requires that rain gauges be installed that measure in 15-minute recording intervals and record 0.1" rainfall intervals. Using the rain gauge data and the radar data, the requirements of the RTS have been met. Table 2.5 below shows each rain gauge and their association to all service areas.

Table 2.5: Rain Gauges & Associated Service Areas

Rain Gauge Locations	Associated Service Areas
004-RG	002, 003, 004, 005, 014, 225
011-RG	006, 007, 011, 012, 013, 203
017-RG	001, 017, 020, 164, 206, 223
023-RG	015, 016, 021, 022, 023, 024, 025, 026, 028, 034, 035, 217
031-RG	027, 030, 031, 032, 033, 043, 051, 204, 224
036-RG	010, 036, 037, 041, 042
045-RG	038, 045
047-RG	044, 046, 047, 048
102-RG	100, 102, 208
103-RG	101, 103, 104, 112, 114, 115, 209
106-RG	098, 105, 106, 107, 111
124-RG	116, 117, 118, 119, 121, 122, 123, 124, 125, 133, 134, 160, 168
145-RG	130, 136, 145, 170
146-RG	132, 135, 142, 146, 163, 165
147-RG	137, 144, 147, 148, 152, 154
153-RG	126, 127, 140, 141, 143, 150, 151, 153
159-RG	113, 131, 159
162-RG	162, 219

Radar Supplemented Data – Explanation of Method

NOAA's NEXRAD radar records reflectivity from objects in the atmosphere and not actual rainfall amounts. However, rainfall rates can be estimated from the reflectivity values using a Z-R relationship. This is the same overall procedure used by independent companies that provide radar rainfall.

$$Z = A * R^B$$

Where: $Z = \text{Reflectivity, } mm^6/m^3$ [also expressed in dBZ; $10 * \text{Log}(Z)$]

$R = \text{Rainfall, } mm/h$

$A, B = \text{Coefficients}$

The NEXRAD default Z-R relationship uses values of 300 and 1.4 for coefficients A and B, respectively; however, a tropical Z-R relationship with values of 250 and 1.2 can be used under some situations.

The NEXRAD Level II data is generally recorded every six minutes on a Polar grid system based on the location of the radar. For this project, each NEXRAD dataset was re-projected onto a Cartesian grid (x,y) and then each grid cell was converted to rainfall rates using the Z-R

relationship. One minute rainfall data was interpolated at each grid cell from the six minute data and then summed together to create five minute and one hour values.

Because the Z-R relationship uses an assumed distribution of raindrop size, the calculated rainfall values are only estimates and need to be adjusted so it compares well with any available rain gages. For the grid cells that contain a rain gage, the rainfall for those grid cells was compared to the rainfall at the rain gages in order to calculate an overall Bias Factor for each storm event. This Bias Factor was then applied to the estimated rainfall value from the NEXRAD data at each grid cell to create an adjusted rainfall coverage. This dataset was used to project rainfall data to sites that had inaccurate or non-existent daily rainfall totals. (the “Radar” datasets noted in the table above) This overall dataset was further refined by calibrating to each daily site’s total volume. This provides the temporal variation of the recorded rainfall at that gauge, giving the RTS-required 5-minute rainfall data. (the “RSD” datasets noted in the table above)

This procedure yields more accurate results than commercially available radar datasets. Commercial rainfall data companies will typically use one bias factor for an entire month’s data, which ignores the constantly shifting atmospheric conditions that impact radar data. By combining the NEXRAD data, which gives a good representation of the variation of rainfall spatially and temporally, with each storm’s rainfall gage data, which is only good in the vicinity of the gage; a rainfall dataset was created that contains volume accuracy at the gage locations while retaining the spatial and temporal information from the radar.

2.4 Data Collection Activities

Using cellular modems, data from the temporary meters was remotely reviewed and collected. The meters were programmed to automatically transmit their collected readings daily to a remote database. If the meter failed to send its data because of poor cellular conditions or other issues, the data analyst would manually connect to the meter via a computer modem and retrieve the data. In the event the meter failed to answer the call from the analyst, a field crew would visit the site, collect the data and address the issues preventing the other collection methods. Data was reviewed weekly, at a minimum, by the data analyst and any unusual conditions noted. This information was regularly transmitted to the City of Hampton. These sheets are included in Appendix D.

Regular maintenance visits were performed by City crews. A record of all of city crew visits to meters (through their work order system) is provided in Appendix D. If the city crews were busy or if there were highly unusual flow readings, the city would call Woolpert and have a Woolpert crew visit the meter location. A record of all Woolpert visits is also included in Appendix D. When Woolpert crews were called to visit a site, they regularly checked the level and velocity recorded by the meter against measured values. Levels were checked by measuring the depth of flow in the pipe with a ruler. If it was different from the sensor reading by more than 0.25 inches, the level reading of the sensor was adjusted within the flow meter software. Velocity was checked with a portable velocity meter and compared to the readings taken by the sensor. The probe velocity could not be adjusted like the level, so if it was determined that the velocity reading might not be accurate then the sensor was typically replaced. If the sensor was replaced, it was treated like a fresh installation.

At the installation and during subsequent periodic site visits, the field crews took manual flow depth and velocity readings and compared to readings collected by the meter. If the meter readings were found to be different than the manual readings, adjustments were made to the meter

calibration or the meter unit and/or sensor were replaced. The collected data was edited based on the observations and calibrations from the field crews. Scatter plots of the level and velocity were prepared and also used to check the data quality.

The permanent flow meters and the rain gauges were all connected to the City of Hampton's existing SCADA system. Telog data collectors were added to some stations within this system to record data at 5-minute intervals at each site and transfer it to a remote database. This data was not RTS-Compliant and was not analyzed to the same level of detail as the area-velocity meters. The additional Area-Velocity meters that were installed in 2009 as supplemental datasets were installed by Woolpert and maintained by city crews just like during the original, RTS-compliant monitoring period.

2.5 QA/QC Procedures

All temporary meter data was processed in accordance with RTS requirements. The collected data was checked by analysts and edited based on the observations and calibrations from the field crews. If there were any missing or obviously erroneous level or velocity data points, the questionable data points were replaced with estimates from a second degree polynomial equation using standard regression techniques. The flow values were then recalculated using the revised data. The ultimate test of sensor performance is accomplished by comparing independent field measurements of depth and velocity to the monitored data. Depth offsets and velocity gain corrections are applied to monitored data based on the field correlation. This process helps to fine tune the depth and velocities used for quantifying flows.

The stability of hydraulics and the performance of both depth and velocity sensors at a site are evaluated using hydrographs and scatter graphs. The daily patterns of rise and fall for both depth and velocity are scrutinized to identify performance issues. At most sites, a rise in depth of flow is accompanied by a rise in velocity, and likewise, a drop in depth is accompanied by a drop in velocity. Whether the flow is uniform free flow or subject to backup conditions, or heavily influenced by a pump station, this distinct repeatable relationship between depth and velocity can be revealed by a scatter graph comparing depth to velocity. When studied over time using either scatter graphs or hydrographs, changes in the relationship can be observed. These changes may indicate sensor performance issues or changing hydraulics possibly due to downstream restrictions, silting, or diversions of flow.

2.6 Procedures for Translating Monitored Basin Information to Unmonitored Basins

A report produced by CDM entitled "Regional Hydraulic Model Dry Weather and Wet Weather Flow Parameters" (2009) outlined the procedures to estimate flow parameters for monitored basins. It also identified typical criteria and suggestions for associating information from monitored basins to unmonitored basins. This report was intended to help standardize the parameter generation across the region. Localities, such as the City of Hampton, will provide these parameters to HRSD for use in the Regional Hydraulic Model (RHM) as required by the consent order.

Basin Association

Basin association is critically important as not all of the basins were monitored. Flow parameters for unmonitored basins have to be extrapolated from information gathered from the monitored

basins and should be done in a consistent manner. Physical factors that typically influence the various flow parameters (i.e., number of houses influences base flows) were incorporated into the association criteria. It should also be noted that the HRSD service areas were broken up into gravity catchments for the modeling work. Individually associating catchments allows different parts of large HRSD basins to be assigned flows closer to their source and supports the Regional Hydraulic Model. It would be more accurate to associate individual catchments to RTS-compliant monitored locations as this would account for the variation in land usage across the large HRSD service areas. However, after discussions between Woolpert, the City of Hampton, and DEQ, all catchments within a single HRSD service area were associated to the same monitored area to be consistent with the SSES plan.

The City of Hampton developed their flow monitoring plan using pipe material, age, system size, proximity to each other, and general similarities in land use as their criteria. For the Locality and Regional hydraulic models to be developed for the SOC, the time variation of flow was of primary importance. Dry-weather diurnal patterns can only be developed using flows coming into the stations. This requires that all stations be associated with an area-velocity meter. The dry-weather diurnal pattern's time variation is dependent on the predominant land usage in the service area, so land usage became the primary association criteria. The land use was quantified using feature classes provided by the city's GIS and broken down into three categories based on the majority land use: Residential, Business/Industrial, or Other. The "Other" category included areas such as parks or mixed-use developments and was investigated in more detail on a case-by-case basis to determine the proper association to a metered basin.

All city service areas were divided into these groups. The pipe material and age were reviewed as the second major criteria. These criteria have an impact on the dry weather infiltration and the wet weather inflow and infiltration response of the basin. Each of the Land Usage groups was sub-divided based on these criteria. The inch-diameter miles for each area were calculated, becoming the third criteria. Each of the sub-divisions was further divided out, with care taken to ensure that there was at least one metered site in each grouping. Proximity to monitored basins and proximity of the basin to a water body were also evaluated.

These additional criteria served as tie-breakers and allowed the adjustment of the bulk groupings to reflect the probable groundwater influence on the site. The result is that all service areas are associated to a monitored site. Table 2.6 shows the criteria for association by their priority/importance. Table 2.7 shows proposed monitored areas and the service areas that have been associated to them.

Please note that Pump Stations 160 and 161 are combined into Service Area 160-PS since they both serve the Hampton Coliseum. Also, Stations 165, 166, and 167 are combined into Service Area 165-PS because all three serve buildings in Sandy Bottom Nature Preserve. Also, Pump Stations 18 and 19 are not included in the service area associations because they have no service area and are excluded from SSES activities.

Table 2.6: Association Procedure

Priority	Category
1	Land Usage
2	Pipe Material and Age
3	System Size
4	Proximity to Meter
5	Proximity to Water Body

Table 2.7: Original Flow Monitoring Locations and Basin Associations

Proposed RTS-Compliant Meter Locations (33 of 104 PSs)	Associated Service Areas
010	None
012	006, 013, 014, 107
015	None
021	004, 005, 016, 017, 020, 101, 217
022	None
023	011, 027, 031, 036, 102, 113, 115, 206, 208, 219, 223, 224
024	None
026	032
035	002, 025, 034
037	001, 105, 106, 111, 114, 134
042	041, 043
044	033, 204, 225
047	030, 046
048	007, 123, 203
051	028, 045
098	None
118	160, 161
121	003, 112, 119, 141
125	127, 131, 133
126	116, 117, 124, 137
130	100, 135, 163
136	None
140	None
142	132
143	103, 104, 122, 164, 209
145	None
146	None
147	148, 165, 166, 167, 168
151	None
154	None
159	None
162	038, 144, 150, 152, 153
170	None

Note – This table is revised after completion of the dry weather flow reliability analysis and presented in Section 3

Unit Hydrographs

The Base Sewage Flow (BSF) Unit Hydrograph is simply a constant unit (1) value hydrograph that describes the daily nature of the customer-generated flows. These unit hydrographs are typically referred to as the diurnal patterns. Per CDM (2009), the diurnal pattern for an unmonitored basin can be directly transferred from a nearby monitored basin with similar land use. The unit hydrographs will be directly transferred from the monitored basin to the associated basin because the land use and proximity are accounted for in the associations. The daily average BSF is required to multiply with the non-dimensional unit hydrograph ordinates to generate the flow rates diurnal flow hydrograph for the basin.

Base Sewage Flow

The RTS recommends that the BSF be determined using billed water consumption data. This is re-iterated in CDM (2009). In the original May 26, 2009 Flow Evaluation Report (FER) Section 3.3, it was stated that the water usage data was not anticipated to be used for estimating base sewage flows in unmonitored areas. The full dataset was not provided by Newport News Water Works until just before the FER submittal on May 26, 2009. Because of this, water usage records were not used with the monitored dataset. Since it is not desirable to make commitments based on data of unknown quality, Section 2.6 of the original May 26, 2009 FER states that base sewage flow was planned to be extrapolated to unmonitored SAs by scaling with sewerage area.

After further analysis of the water consumption data, it was determined that the return percentage of the monitored basin will be transferred to the associated basins. The return percentage will be applied to the billed water consumption in the unmonitored basin to calculate the BSF in the unmonitored basin.

Dry Weather Infiltration

As was discussed in CDM (2009) Dry Weather Infiltration (DWI) is a function of sanitary sewer conditions, groundwater levels, and soil conditions within the basin. These parameters were taken into account when developing basin associations. The DWI in unmonitored basins were calculated using the ratio of inch-diameter-mile (IDM) in the monitored basin versus the unmonitored basin. (ie, an unmonitored basin that has half of the IDM of its associated monitored basin will have half of the DWI of the monitored basin)

Average Daily Flow

Since the BSF and DWI are extrapolated from information from the monitored basins, the Average Daily Flow (ADF) for unmonitored basins is calculated as the sum of the extrapolated BSF and DWI.

Wet Weather Unit Hydrograph Parameters (RTK method)

The RTK unit hydrograph method for estimating a basin's response to wet weather events has been utilized for this analysis. Per CDM (2009), the unit hydrograph parameters for unmonitored catchments can be directly transferred from nearby monitored catchments with similar sewer age, gravity sewer construction materials, construction practices, rehabilitation history, etc. These factors were taken into consideration when associating basins. The RTK triangular unit hydrograph parameters for monitored catchments will be directly transferred to unmonitored catchments.

Non-RTS-Compliant Monitored Locations

As was discussed previously in Section 2.2 above, some basins have non-RTS-compliant area-velocity monitoring data suitable for dry weather flow analysis. These basins are still associated to an RTS-compliant monitoring site for wet weather flows. However, reliable dry weather flow parameters are much better than anything calculated through association. BSF, DWI, ADF, and diurnal patterns will be calculated from the dry weather area-velocity data at locations with these area-velocity meters. Calculation of these dry weather parameters at these non-compliant monitored locations will be discussed in Sections 3.3 and 3.4. Since the sites are non-compliant, wet weather unit hydrograph parameters at these non-compliant locations will be transferred through association in the same way as an unmonitored site.

Non-RTS-compliant basins that have SCADA daily totals will use this information for dry weather days only. The SCADA-reported ADF will be used to scale up the ADF that was previously calculated through the procedures outlined above. This uses the non-compliant data to supplement the RTS-compliant dataset.

3.0 MONITORED FLOW CHARACTERIZATION AND ASSESSMENT

3.1 Data Analysis Overview

The data was analyzed using the methods specified in Section 3.5 of the RTS. This method separates the flow into dry and wet weather components. The dry weather component is the Dry Weather Average Daily Flow (ADF). The wet weather component is Rainfall Derived Inflow/Infiltration (RDII). The ADF is further separated into BSF and DWI. The ADF and the RDII are used to prioritize SSES activities and to estimate the parameters for construction of sewer models as required by Section 6 of the RTS.

Three of the metered sites (022-PS, 098-PS and 170-PS) produced extremely low flows. The conditions at these sites were below the operating range of the flow meters so these meters were removed from further data collection and the service areas were associated to other monitored service areas. Three other meters (015-PS, 042-PS and 044-PS) produced low flows but were within the operating range of the meters. These meters remained in service and the data analyzed where possible. Table 3.1 provides a summary of the gravity flow sites including the size of the sewered area.

Table 3.1: Summary of Flow Monitoring Sites and Sewered Areas

Meter	Sewered Area (Acres)	Meter	Sewered Area (Acres)
010-PS	64	140-PS	94
012-PS	105	142-PS	143
015-PS	47	143-PS	263
021-PS	69	145-PS	104
023-PS	465	146-PS	445
024-PS	39	147-PS	203
026-PS	79	151-PS	164
035-PS	59	154-PS	335
037-PS	251	159-PS	40
042-PS	144	162-PS	35
044-PS	239	121-PS	40
047-PS	62	125-PS	134
048-PS	563	126-PS	213
051-PS	37	130-PS	101
118-PS	49	136-PS	156

3.2 Dry Weather Flow Reliability Analysis

As required by the RTS, the dry weather flow monitoring conducted must meet a 75% data reliability standard on a monthly basis. Table 3.2 on the following page shows that all but two of the monitored sites meet this criterion (015-PS and 130-PS). Site 130-PS missed the 75% criteria with a 67% reliability factor that was caused by a combination of a short term meter malfunction and the significant rain events in September 2008. However, Site 130-PS does provide significant reliable dry weather flow data in prior

months that is of better quality data versus ignoring all its data and using dry weather data from an associated flow meter.

Table 3.2: Summary of Dry Weather Flow Monitoring Sites Reliability Analysis

	Meter	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08
010-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
012-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	1%	0%	0%	0%	0%	0%
015-PS	Reliability	100%	100%	100%	40%	41%	85%
	Surcharge	3%	0%	0%	0%	0%	0%
021-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
023-PS	Reliability	100%	100%	100%	100%	100%	99%
	Surcharge	0%	0%	0%	0%	0%	1%
024-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	2%	1%	16%	4%	39%
026-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	4%	0%	0%	0%	4%	1%
035-PS	Reliability	100%	100%	100%	100%	99%	99%
	Surcharge	0%	0%	0%	0%	0%	1%
037-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
042-PS	Reliability	100%	100%	77%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
044-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	1%	0%	0%	0%
047-PS	Reliability	88%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	2%	0%	0%	0%
048-PS	Reliability	100%	100%	100%	100%	99%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
051-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
118-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
121-PS	Reliability	100%	98%	100%	100%	100%	100%
	Surcharge	1%	0%	0%	0%	0%	0%
125-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
126-PS	Reliability	100%	98%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	8%
130-PS	Reliability	93%	100%	100%	97%	100%	67%
	Surcharge	4%	0%	0%	0%	0%	1%
136-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
140-PS	Reliability	100%	100%	100%	100%	99%	100%
	Surcharge	0%	0%	0%	0%	5%	2%

Meter		Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08
142-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
143-PS	Reliability	100%	100%	100%	100%	100%	98%
	Surcharge	0%	0%	0%	0%	0%	0%
145-PS	Reliability	100%	100%	100%	97%	97%	100%
	Surcharge	1%	0%	0%	0%	0%	3%
146-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
147-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
151-PS	Reliability	100%	100%	96%	94%	89%	100%
	Surcharge	0%	0%	1%	1%	0%	0%
154-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	6%	0%	0%	0%	0%	5%
159-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	1%	0%	1%	0%
162-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

Additional Flow Monitoring

An additional set of twelve (12) locations were temporarily metered from 3/11/09 to 7/7/09 with open channel area-velocity meters. This data collection effort resulted in non-RTS compliant data because it did not capture the three required rainfall events. However, this data is useful because the locations monitored were selected to help gain a better understanding of the base sewage flow and dry weather infiltration in areas not covered by the original flow monitoring period in 2008. The primary goal of this additional flow monitoring was to obtain information on the city's non-terminal service areas for these limited modeling purposes. It should be noted that there have not been any new associations created by this additional flow monitoring. Table 3.3 on the following page shows the locations of the additional flow monitoring sites, and the dry weather reliability analysis that was performed to confirm accurate data was obtained.

Non-terminal areas have been defined throughout the region as city-owned gravity lines that connect to HRSD gravity interceptors. There are approximately 1,262,000 LF of city gravity pipe in non-terminal service areas. In total, non-terminal areas contain over 50% of the city owned gravity lines. This includes city pump stations whose force mains discharge to city gravity lines that ultimately drain to HRSD gravity interceptors. Some of these "piggy-back" city service areas were monitored during the original monitoring plan, but none of the areas that directly drain to HRSD lines were covered. As information on the HRSD master metering plan was finalized and shared with the localities, it was determined that the city could not extract as much information from the proposed HRSD meters as was initially hoped. This created mass-balance problems for these portions of the City's model that needed resolution.

There are approximately 300 individual connections to HRSD in the non-terminal areas, and nearly all are too small to effectively install area velocity meters and capture flow data. However, seven (7) metering locations could monitor approximately 386,000 LF of the 1,262,000 LF in non-terminal service areas.

The remaining five (5) monitored areas were at city pump stations where more information was desired that the initial flow monitoring plan did not capture.

Overall, this additional meter data will allow the city to refine its dry weather flow estimates. An additional benefit gained by this metering effort is that some of the city system's response to the June 5, 2009 event was captured. This event is one that CDM and HRSD have investigated during their wet weather model calibration. While this dataset is not fully RTS-compliant, having this additional information allows for better model calibration during wet weather events.

Table 3.3: Summary of Additional Dry Weather Flow Monitoring Sites Reliability Analysis

Meter		Mar-09	Apr-09	May-09	Jun-09	Jul-09
011-100-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	1%	0%	0%	2%	0%
106-PS	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
119-PS_P1	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	1%	0%	0%	0%
119-PS_P2	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
133-PS	Reliability	65%	88%	100%	100%	100%
	Surcharge	4%	0%	0%	0%	0%
134-PS	Reliability	100%	100%	100%	100%	100%
	Surcharge	1%	1%	2%	1%	0%
203-282-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
208-191-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	33%	0%	3%	4%	0%
219-140-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
219-214-M	Reliability	100%	100%	96%	100%	100%
	Surcharge	0%	0%	2%	1%	0%
223H-121-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	11%	0%	2%	1%	0%
224-145-M	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
225-168-M1	Reliability	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%
225-168-M2	Reliability	100%	66%	79%	100%	100%
	Surcharge	0%	0%	0%	0%	0%

Non-RTS Compliant Daily Flow Monitoring Sites

The City of Hampton's SCADA system gathers data from pump stations and stores it on a daily basis. This data includes flow and run-time for most sites. The City of Hampton added mag-meters and Telog data loggers to some of their pump stations to record more frequent pressure, level, and flow data. In addition, HRSD has provided the City of Hampton access to their web-based Telog data server so that data from some of their pump stations located in the City of Hampton may also be used.

The data from these city pump stations is useful for modeling and some analysis of hydraulic conditions, but it is not useful for conducting RTS Compliant RDII analysis. A summary of the non-compliant pump station and area-velocity meter data available is included in Table 3.4.

Table 3.4: Summary of Non-RTS-Compliant Flow Monitoring Sites

Location	Sewered Area (ac)	Meter Type	Information Collected
001-PS	147	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
003-PS	22	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
004-PS	26	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
005-PS	42	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
006-PS	127	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
007-PS	294	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
011-PS	442	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
013-PS	93	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
014-PS	268	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
016-PS	39	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
017-PS	166	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
027-PS	359	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
030-PS	58	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
031-PS	228	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
032-PS	78	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
033-PS	219	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
034-PS	50	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
036-PS	384	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
041-PS	261	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
043-PS	128	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
100-PS	34	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
102-PS	242	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
103-PS	82	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
104-PS	238	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
105-PS	87	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
106-PS	631	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
107-PS	148	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
111-PS	220	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
112-PS	28	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
113-PS	445	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
114-PS	167	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
115-PS	477	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
116-PS	82	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
117-PS	44	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
119-PS	408	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
123-PS	182	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
124-PS	418	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
127-PS	363	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
131-PS	390	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
132-PS	263	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times

Location	Sewered Area (ac)	Meter Type	Information Collected
133-PS	327	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
134-PS	280	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
135-PS	116	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
137-PS	293	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
141-PS	199	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
153-PS	245	Magmeter	Dry Weather Daily Flow Totals, Pump Run Times
011-PS	459	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
106-PS	660	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
119-PS	594	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
133-PS	409	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
134-PS	373	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
203-282-M	150	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
208-191-M	883	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
219-140-M	1419	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
219-214-M	859	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
223H-121-M	298	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
224-145-M	255	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)
225-168-M	159	Area/Velocity	Dry Weather Flows (Diurnal Hydrographs, ADF, BSF, DWI)

Dry Weather Flow Data Analysis Conclusions

As concluded earlier in this section, three of the metered sites (022-PS, 098-PS and 170-PS) produced extremely low flows. The conditions at these sites were below the operating range of the flow meters so these meters were removed from further data collection and the service areas were associated to other monitored service areas. In addition, since flow monitored sites 015-PS and 130-PS did not meet the dry weather reliability analysis criteria, they too are considered not meeting the wet weather reliability requirements. Table 3.5 on the following page shows updated meter site re-associations as a result of this dry weather flow analysis. Basin re-associations were conducted in accordance to the guidelines identified in Section 2.

Table 3.5: Service Area Associations after Dry Weather Analysis

RTS-Compliant Dry Weather Flow Meter Locations (28 of 104 PSs)	Associated Service Areas
	¹ Re-Associated Basins based on Dry Weather Analysis
010	None
012	006, 013, 014, 107
021	004, 005, 015¹ , 016, 017, 020, 101, 217
023	011, 022¹ , 027, 031, 036, 102, 113, 115, 206, 208, 219, 223, 224
024	None
026	032
035	002, 025, 034
037	001, 105, 106, 111, 114, 134
042	041, 043
044	033, 204, 225
047	030, 046
048	007, 123, 203
051	028, 045
118	160, 161
121	003, 112, 119, 141
125	127, 131, 133
126	116, 117, 124, 137
136	None
140	None
142	132
143	100¹ , 103, 104, 122, 130¹ , 135¹ , 163¹ , 164, 209
145	None
146	None
147	148, 165, 166, 167, 168
151	None
154	None
159	None
162	038, 098¹ , 144, 150, 152, 153, 170¹

3.3 Water Usage for Base Flow Development

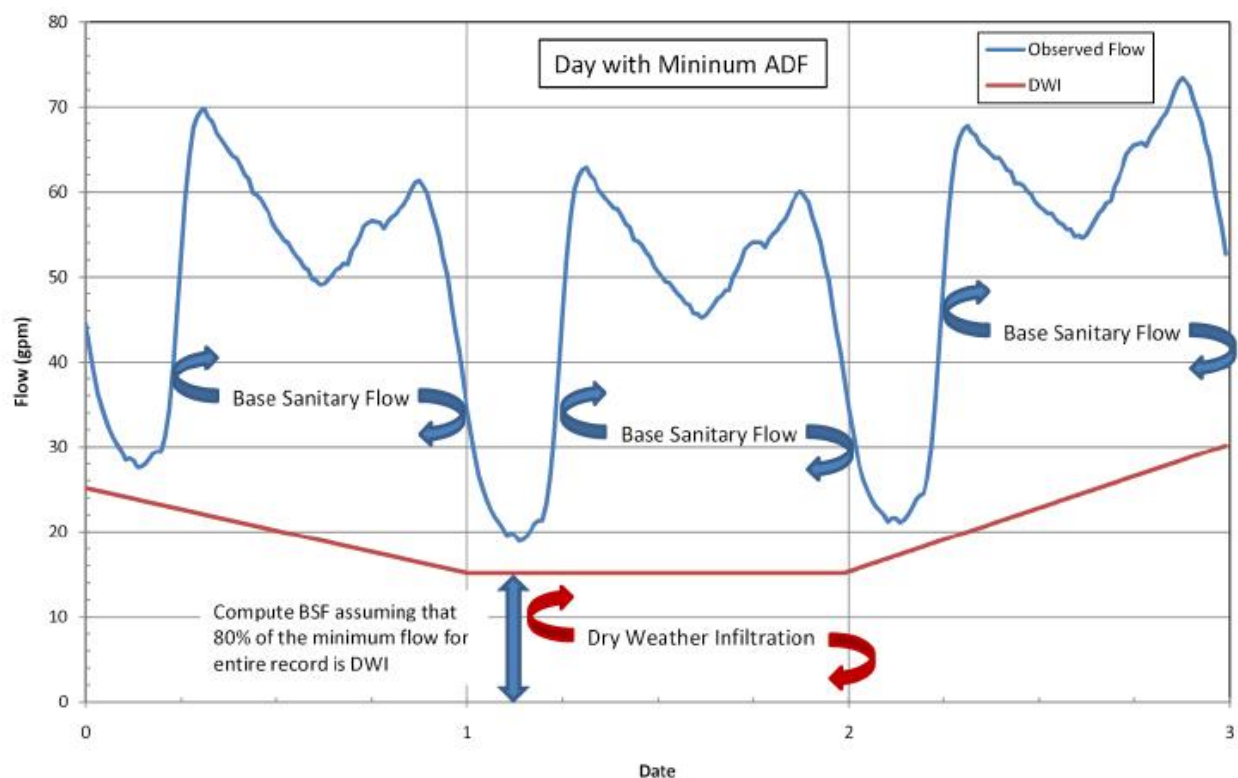
The RTS requires localities to use water consumption data to determine base sewage flow. The City of Hampton received limited data for four individual days from Newport News Water Works (NNWW) on September 24, 2008 to assist with the SSES plan development. Only one of those days fell within the monitoring period. Section 3.5.1.1 of the RTS requires that base flow analysis be performed “assuming 100% of the metered water consumption is returned to the sanitary sewer collection system as sewage flow.” Return percentages for metered locations could not be accurately determined from that water usage dataset because it did not cover the entire flow monitoring period of April 2008-September 2008. However, the information was sufficient for the SSES plan’s determination of non-residential flows. City-wide water consumption data covering the entire monitoring period was received from NNWW on May 11, 2009. As was reported in the original FER, initial analysis indicated that the water consumption data was much more than the billed water consumption. With the short time frame, there was insufficient

time to re-evaluate all BSF values so analysis started with the intention of incorporating potential changes into the Flow Parameter Database on June 12, 2009.

Upon further review of the water consumption data, it became evident that there was a unit conversion problem. This problem has since been rectified. However, billed water consumption is still typically higher than the monitored flow volumes at the RTS-Compliant temporary open-channel meters, at the non-RTS-compliant SCADA recorded daily totals, and at the non-RTS-compliant Telog-equipped force main recording stations. Return percentages at RTS-Compliant meters typically ranged from 23% to 70% with two locations having return percentages right at 100% and two other locations having their measured ADF more than 140% of water consumption. For all meters except these last two noted locations, using “100% of the metered water consumption” as required by the RTS to generate base sewage flows was not feasible. Using this value would show zero infiltration into most of the system. Significant areas of the city would actually show exfiltration (flow out of the system) of approximately 50% of the ADF. This is not likely.

An alternative method of calculating BSF from the area-velocity meter data was used. RTS Section 3.5.1.3 states that “Engineering judgment shall be applied in the estimation of DWI.” Standard industry rule of thumb is that 80% of the minimum dry weather flow can be defined as dry weather infiltration. This is confirmed as an accepted practice for the region in CDM’s document “*Regional Hydraulic Model Dry Weather and Wet Weather Flow Parameters*” that was revised March 25, 2009. The diurnal hydrograph for the dry weather flow at any area-velocity meter was computed from an average of the hydrographs of the 6 lowest weekday and the 6 lowest weekend ADF days during the monitoring period that had reliable data. The 80% value was applied to the lowest flow on that average dry weather day. Once the DWI was determined, this value was subtracted from the measured ADF to provide the BSF. Figure 3.1 (reproduced from CDM 2009) shows this procedure.

Figure 3.1: DWI Calculation as 80% of Minimum Dry Flow



Water consumption data from Newport News Water Works was also analyzed to determine any potential seasonal variations in base flows. The meters were not in areas with seasonally-varying occupancy so variations in consumption were not expected. 6 locations that did show a variation in water consumption were analyzed and the variations were determined to be from lawn maintenance/irrigation activities. Since these activities do not contribute to base flows, it was determined that none of the monitored areas had seasonally-varying base flows.

Non-RTS-Compliant area velocity meters that were reliable during dry weather were analyzed in this same way. This data was used at those individual meter locations in place of associated data. No other meters were associated to these non-compliant meter datasets. Non-RTS-compliant SCADA daily total data was also used to supplement the associated data. The BSF, DWI, ADF, and dimensionless unit hydrographs were first prepared at the SCADA site in the same way that they would be for an unmonitored site. This is what is required by the RTS. The SCADA-reported ADF was then used to scale up or down the associated BSF, DWI, and ADF values. This procedure effectively scales up the calculated flow to the observed flow and provides a dataset that is RTS-compliant but supplemented by additional data to provide the most accurate depiction of flows in the city of Hampton.

As an example: Basin 003-PS was not an RTS-compliant monitored site so it was associated to RTS-compliant meter 121-PS. However, 003-PS has a non-RTS-compliant magmeter that reports daily flow totals through the city's SCADA system. As required by the RTS, flows at 003-PS were calculated from association to the RTS-compliant meter as was described in Section 2.6 above. The ADF projected at 003-PS was calculated to be 10,900 gallons per dry weather day. The BSF and DWI at this location were calculated as 8,200 and 2,700 gallons per dry weather day respectively. An average of the 9 lowest dry weather day flows recorded through the SCADA system (using dry weather days that were common among RTS-compliant meters) indicated the flow should be approximately 36,000 gallons per dry weather day. To use this SCADA data to supplement the RTS-compliant data, the BSF and DWI were both multiplied by a factor of 3.29. This keeps the RTS-compliant proportions between BSF and DWI but helps to adjust for mass balance issues across the city. In this fashion, the SCADA data is used to supplement the BSF, DWI, and ADF computed from the RTS-compliant dataset.

3.4 Dry Weather Infiltration Analysis

As was discussed in the previous section, the Dry Weather Infiltration (DWI) was calculated as 80% of the minimum flow on a typical dry weather day for both RTS-compliant and non-RTS-compliant Area-Velocity metered locations. Since DWI depends heavily on the amount of pipe in the ground, DWI is scaled from monitored basins to unmonitored basins on the ratio of Inch-Diameter-Miles.

There are eight area-velocity meters that show a seasonal variation in dry weather infiltration. Meters in basins 010-PS, 021-PS, 024-PS, 026-PS, 037-PS, 042-PS, 154-PS, and 159-PS showed variations in the ADF during the metering period. Analysis of diurnal hydrographs during the high, or "spring," and low, or "fall," periods indicated that the shape of the hydrograph and the magnitudes of the peaks did not show a significant change. This indicates that the customer-generated flows remained relatively constant during the monitoring period. To verify this, the water consumption in these eight areas was examined in further detail. Basins 010-PS, 021-PS, and 024-PS showed some variation in water consumption. Since these areas are small and almost exclusively residential, this change is attributed to lawn maintenance/irrigation. Also, the water consumption at these three locations each changed by approximately 25% while the ADF at each of these locations changed by 50% or more. Water consumption variations at the other 5 basins varied less than 10%. This analysis shows that these basins have a seasonal variation in dry weather infiltration.

Separate BSF and DWI values were calculated for each of these two seasons in the same way that they were calculated for the entire monitoring period. The “spring” values refer to the time of higher groundwater and will be applied between mid-January and mid-July. The “fall” values correspond to the season with lower groundwater and will be applied from mid-July to mid-January.

A system-wide analysis showed that the city had dry weather infiltration issues common to flat, low-lying areas. In other parts of the country, DWI would be much less than the BSF. However, shallow coastal areas such as Hampton tend to have higher rates of DWI that can almost equal the customer-generated BSF. Monitored service areas 047-PS and 048-PS exemplify this effect. The collection system in these areas winds around water bodies in this flat, marshy area of the city. Pump station 048-PS serves such a large, flat area that it has some very deep gravity pipelines which contribute to this problem. With these two service areas being so close to the water, it was assumed that there should be a seasonal variation in their DWI. This was not the case, as the dry weather infiltration rates were discovered to be constantly high.

3.5 Dry Weather Flow Analysis

For each gravity meter site, the dry weather flow days were initially identified by excluding days with rainfall and the following 3 days. Also, care was taken to avoid other abnormal conditions as can be noticed in the flow data, e.g., erroneous or missing records, special events. Dry weather diurnal flow hydrographs for weekdays, Saturdays, and Sundays were computed by averaging the 5-minute flows into 15-minute flows of respective dry weather flow days. These flows were then averaged by time of day to determine the average diurnal pattern of flow for each site. As was mentioned in Section 3.4, eight of the meter sites showed significant seasonal differences in dry weather flow. The "spring" pattern was observed from the start of metering through mid-July and the "fall" pattern was observed from mid-July through the end of the metering period. Two different typical diurnal patterns were developed for sites 010-PS, 021-PS, 024-PS, 026-PS, 037-PS, 042-PS, 154-PS and 159-PS to accurately model these systems. No metering locations had a marked variation in base sewage flows, although some variation does occur with homeowners irrigating their lawns.

To support the Regional Hydraulic Model, one BSF value representing both week days and weekend days was used to develop dimensionless diurnal hydrographs. One DWI was also required, and it is a week-long weighted average as well. The ADF is the sum of the BSF and DWI. These parameters and dimensionless diurnal patterns are intended to provide one set of annual average parameters for RHM development. The RHM also asks for peak season parameters, so those values will be provided. The dry weather flow values reported below in Table 3.6 are the annual average values and area equal to the ones submitted to HRSD in the Flow Parameter Database dated March 15, 2010.

Table 3.6: Dry Weather Flow Parameter Summary

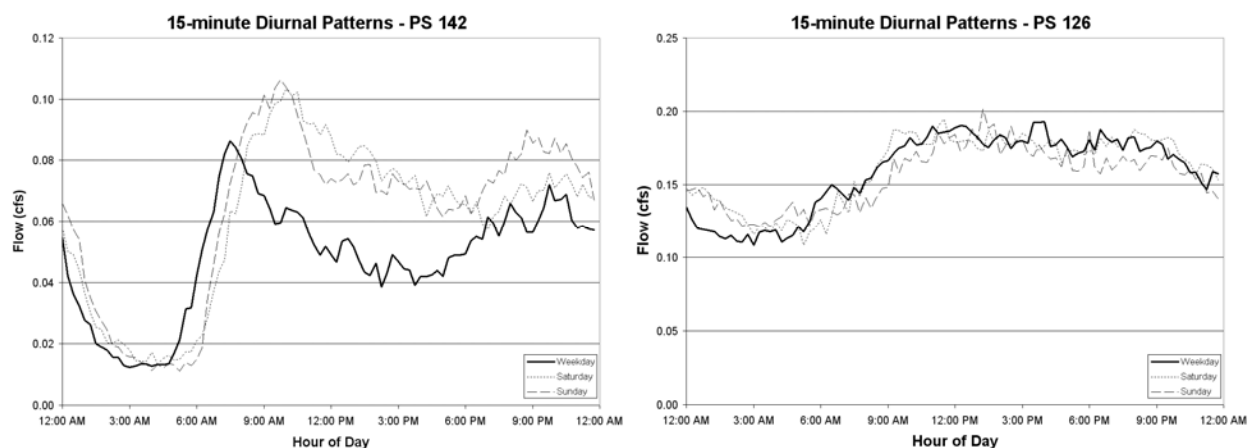
Flow Meter	ADF (GPM)	BSF (GPM)	DWI (GPM)
010-PS	11.0	6.5	4.5
012-PS	27.3	16.0	11.3
021-PS	56.0	35.3	20.7
023-PS	118.5	80.0	38.5
024-PS	41.4	19.2	22.3
026-PS	23.3	14.7	8.6
035-PS	54.3	29.3	25.0
037-PS	46.0	31.3	14.7

Flow Meter	ADF (GPM)	BSF (GPM)	DWI (GPM)
042-PS	119.9	59.0	60.9
044-PS	25.2	18.8	6.4
047-PS	32.1	13.6	18.5
048-PS	216.8	102.5	114.4
051-PS	25.5	15.0	10.5
118-PS	98.5	66.1	32.4
121-PS	6.0	3.5	2.5
125-PS	18.5	9.0	9.5
126-PS	72.2	35.2	37.0
136-PS	40.3	30.5	9.8
140-PS	46.2	20.0	26.2
142-PS	23.3	18.9	4.4
143-PS	23.5	14.4	9.1
145-PS	28.0	21.2	6.8
146-PS	82.7	60.4	22.2
147-PS	64.8	49.8	15.1
151-PS	48.7	34.2	14.4
154-PS	59.7	38.3	21.4
159-PS	9.7	6.7	3.0
162-PS	7.3	5.2	2.1

3.6 Typical Dry Weather Diurnal Pattern

Figure 3.2 shows examples of diurnal patterns observed in the City of Hampton. PS-142 has a diurnal pattern typical of a residential area. PS-126 has a pattern typical of a mixed residential/commercial area. Note also that PS-126 has elevated relative flows during off peak hours. This indicates a high level of DWI. These patterns represent the average Weekday, Saturday, and Sunday diurnal variation in flows. For the Regional Hydraulic Model, only one weekend pattern was requested, so the Saturday and Sunday hydrographs were averaged together for that dataset. Dry weather diurnal patterns that were provided to HRSD are included in Appendix E and on the data disk.

Figure 3.2: Example Diurnal Patterns – PS 142 and 126



3.7 Wet Weather Flow and Rainfall Analysis

Rainfall Dependent Inflow and Infiltration

RDII was calculated by subtracting the typical dry weather diurnal flow from the observed flow. The temporal characteristics of the RDII response was then analyzed using the SSOAP program developed by CDM. This program allows the user to estimate the RDII response of a defined storm using the RTK method. RTK is a unit hydrograph method for estimating RDII. Rainfall and flow data for each gravity meter was used with the SSOAP program to evaluate the system's response to wet weather. The SSOAP program allows the user to separate dry weather flows from wet weather flows to see just the RDII.

The RTS required the flow monitoring program to record a sufficient amount of dry weather data to adequately determine the ADF. The RTS also required the flow monitoring program to record data during three individual storm events greater than one inch of accumulation, including at least one event with a one-year recurrence interval. The one-year recurrence storm occurred on September 25, 2008. Table 3.7 on the following page the individual storms and the accumulated depths recorded by each rain gauge. The storms highlighted in yellow exceed one inch of accumulation, and the storms highlighted in red exceed the one-year recurrence interval. While two rain gauges did not record the one-year event, all flow meters were in the areas of the city where the covering rain gauge did experience the one-year event. These locations are shown in Figure 2.5.

Table 3.7: Storm Events and Rainfall Depths in Inches

Storm Event	1	2	3	4	5	6
Date	4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
004-RG	0.81	1.63	1.18	0.56	0.37	2.90
011-RG	1.96	1.35	1.47	0.90	1.53	3.51
017-RG	1.14	1.56	1.50	0.99	0.08	4.30
023-RG	2.05	1.26	1.16	0.95	0.31	3.93
031-RG	1.91	1.41	1.66	0.84	1.26	3.90
036-RG	0.90	1.05	1.06	0.87	0.32	3.73
045-RG	1.45	0.72	0.59	0.84	1.28	2.62
047-RG	1.75	0.83	0.94	0.86	1.52	3.09
102-RG	1.82	2.14	1.14	1.01	0.06	3.70
103-RG	2.09	1.44	0.65	1.28	0.08	3.64
106-RG	1.83	1.75	1.27	1.01	0.10	3.73
124-RG	2.28	1.49	1.32	1.12	0.09	3.63
145-RG	1.58	0.53	1.18	1.40	0.28	3.25
146-RG	1.88	0.77	1.08	0.76	0.12	3.96
147-RG	1.77	0.66	0.14	1.17	0.09	3.36
153-RG	2.00	0.90	1.05	1.17	0.08	3.40
159-RG	1.76	1.42	1.34	0.90	0.04	3.45
162-RG	1.67	1.53	0.74	1.50	0.06	4.67

Note that there was significant variation in depths recorded during the smaller storm events. This is typical of summer and fall thunderstorms spread over a city as wide as Hampton. For this reason, six different storms were needed for each rain gauge to achieve the required three sufficient storms. Depth-Duration-Frequency curves for each of the six storms are included in Appendix B.

Wet Weather Flow Reliability Analysis

As required by the RTS, the wet weather flow monitoring conducted must meet a 90% data reliability standard during qualifying rain events. To assess the impact of the unreliable data on the wet weather flows, Table 3.8 on the following page shows comparisons were performed at each site for each storm event. Data must be greater than 90% reliable during wet weather flows to be considered usable. Site 047-PS had unreliable data during the April 21, 2008 storm, and it had reliable data only during one other 1-inch event (9/10/08) as well as the 2-year event so it does not meet the reliability requirements and has been determined to be a non-RTS compliant meter site. Site 047-PS shall be re-associated to another meter site in accordance to the RTS requirements which are provided in Section 2. This re-association is shown in the table at the end of this section.

Table 3.8: Summary of Wet Weather Flow Monitoring Sites Reliability Analysis

“Non-RTS Compliant” shown in Table 3.5: Meter data during the rain event was not suitable for developing stage-storage curves to calculate true inflow rates during tail water and surcharging conditions.

Summary of Wet Weather Flow Monitoring Sites Reliability Analysis

011-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying	Qualifying	Qualifying		Qualifying	Qualifying
		1.96", < 1 yr event	1.35", < 1 yr event	1.47", < 1 yr event	0.90", < 1 yr event	1.53", < 1 yr event	3.51", > 1yr event
012-PS	Reliability	Non-RTS Compliant	100%	100%	100%	100%	100%
	Surcharge	8%	0%	0%	0%	0%	0%

023-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying	Qualifying	Qualifying			Qualifying
		2.05", < 1 yr event	1.26", < 1 yr event	1.16", < 1 yr event	0.95", < 1 yr event	0.31", < 1 yr event	3.93", > 1yr event
021-PS	Reliability	100%	100%	100%	99%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
023-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	3%
024-PS	Reliability	100%	Non-RTS Compliant	Non-RTS Compliant	Non-RTS Compliant	Non-RTS Compliant	Non-RTS Compliant
	Surcharge	0%	4%	5%	46%	33%	36%
026-PS	Reliability	100%	Non-RTS Compliant	Non-RTS Compliant	100%	100%	100%
	Surcharge	0%	24%	9%	0%	0%	0%
035-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

031-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying	Qualifying	Qualifying		Qualifying	Qualifying
		1.91", < 1 yr event	1.41", < 1 yr event	1.66", < 1 yr event	0.84", < 1 yr event	1.26", < 1 yr event	3.90", > 1yr event
051-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	1%	0%	0%	0%	0%	0%

036-RG

Meter Location		4/21/08	8/10/08 Qualifying	8/15/08 Qualifying	9/5/08	9/10/08	9/25/08 Qualifying
		0.90", < 1 yr event	1.05", < 1 yr event	1.06", < 1 yr event	0.87", < 1 yr event	0.32", < 1 yr event	3.73", > 1yr event
010-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
037-PS	Reliability	100%	100%	100%	99%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
042-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

047-RG

Meter Location		4/21/08 Qualifying	8/10/08	8/15/08	9/5/08	9/10/08 Qualifying	9/25/08 Qualifying
		1.75", < 1 yr event	0.83", < 1 yr event	0.94", < 1 yr event	0.86", < 1 yr event	1.52", < 1 yr event	3.09", > 1yr event
044-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
047-PS	Reliability	58%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
048-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

124-RG

Meter Location		4/21/08 Qualifying	8/10/08 Qualifying	8/15/08 Qualifying	9/5/08 Qualifying	9/10/08	9/25/08 Qualifying
		2.28", < 1 yr event	1.49", < 1 yr event	1.32", < 1 yr event	1.12", < 1 yr event	0.09", < 1 yr event	3.63", > 1yr event
118-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
121-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
125-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

145-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 1.58", < 1 yr event	0.53", < 1 yr event	Qualifying 1.18", < 1 yr event	Qualifying 1.40", < 1 yr event	0.28", < 1 yr event	Qualifying 3.25", > 1yr event
136-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	4%
145-PS	Reliability	100%	81%	100%	100%	100%	100%
	Surcharge	6%	0%	0%	0%	0%	26%

146-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 1.88", < 1 yr event	0.77", < 1 yr event	Qualifying 1.08", < 1 yr event	0.76", < 1 yr event	0.12", < 1 yr event	Qualifying 3.96", > 1yr event
142-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
146-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	1%	0%

147-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 1.77", < 1 yr event	0.66", < 1 yr event	0.14", < 1 yr event	Qualifying 1.17", < 1 yr event	0.09", < 1 yr event	Qualifying 3.36", > 1yr event
147-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
154-PS	Reliability	Non-RTS Compliant	100%	100%	100%	100%	Non-RTS Compliant
	Surcharge	33%	0%	0%	0%	0%	15%

153-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 2.00", < 1 yr event	Qualifying 0.90", < 1 yr event	Qualifying 1.05", < 1 yr event	Qualifying 1.17", < 1 yr event	Qualifying 0.08", < 1 yr event	Qualifying 3.40", > 1yr event
126-PS	Reliability	100%	100%	100%	100%	Non-RTS Compliant	100%
	Surcharge	0%	0%	0%	1%	16%	0%
140-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	1%	0%	0%	0%	6%	5%
143-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%
151-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

159-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 1.76", < 1 yr event	Qualifying 1.42", < 1 yr event	Qualifying 1.34", < 1 yr event	Qualifying 0.90", < 1 yr event	Qualifying 0.04", < 1 yr event	Qualifying 3.45", > 1yr event
159-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	10%	0%	0%	2%

162-RG

Meter Location		4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
		Qualifying 1.67", < 1 yr event	Qualifying 1.53", < 1 yr event	Qualifying 0.74", < 1 yr event	Qualifying 1.50", < 1 yr event	Qualifying 0.06", < 1 yr event	Qualifying 4.67", > 1yr event
162-PS	Reliability	100%	100%	100%	100%	100%	100%
	Surcharge	0%	0%	0%	0%	0%	0%

Method for Calculating True Inflow Rate During Surcharged and Tail water Conditions

The gravity flow meters used in this study were able to record level, velocity, and flow rate during both low flow and surcharge conditions.

The method used to approximate the true inflow rate of surcharged or tail water condition data is a stage-storage method that accounts for the storage the collection system upstream of the meter location. This method also allows for the adjustment of tail water-impacted flow data. To complete this analysis, a stage-storage curve is developed. The stage-storage curve describes the amount of stored volume in the collection system for any given water level. This is calculated knowing the elevations of all pipe and manhole inverts, and pipe and manhole diameters to compute the volume of available storage. Any given water level recorded at a meter corresponds to some amount of storage in the system. When a meter surcharges or experiences tail water conditions, the flow through the pipe is limited by the pipe size and slope. As the water level at the meter changes over time, the stage-storage curve tells how much volume was gained or lost in the system during that time. The true inflow rate into the system is equal to the flow through the meter plus the change in volume divided by the time interval between readings. This method is based on what was used by the City of Suffolk and James City Sewer Authority and was presented in their Flow Evaluation Reports.

It was initially attempted to determine events with potential tail water impact by using the Alarm System connected to the city's SCADA system. The complete list of stations that experienced high wet well alarms during the time frame of the 6 storm events is included in Appendix H. However, it was found that the high wet well alarms were above the crown of the influent pipe. There was the possibility that an event could be tail water impacted and even surcharge without the alarm being tripped, so this record of alarms was not useful for determination of tail water conditions. Visual inspection of the gravity flow meter data during the storm events was conducted and events where the recorded level increased and the recorded velocity decreased were identified as being tail water impacted. The threshold levels were identified for each event as the point where any levels above this required correction using the Stage-Storage method. Table 3.9 on the following page identifies which meters and the depth of flow during a specific rain event where the reduced the peak flow recorded at the meter is caused by the tail water condition.

Table 3.9: Meter Sites with Tail Water Conditions

		Depth of Flow Creating Tail Water Conditions (inches)					
Meter	Pipe Dia. (inch)	4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08
010-PS	9.88						
012-PS	9.75	9.75					
021-PS	9.5						
023-PS	11.5						5.31
035-PS	7.88						
037-PS	7.88						
042-PS	7.75						
044-PS	9.64	3.69					
048-PS	15.88						
051-PS	8	3.15	4.66			2.68	
118-PS	11.68						
121-PS	8	4.11					
125-PS	7.88						
126-PS	7.88				6.1	6.78	3.83
136-PS	10						3.36
140-PS	10	5.67				6.73	9.59
142-PS	10.25						
143-PS	15.88						3.6
145-PS	10.35	4.28					6.59
146-PS	11.75					11.75	
147-PS	14						
151-PS	12.25						
159-PS	7.63			3.8		6.26	7.63
162-PS	8.25						
			>1" Rain				
			> 1-year Event				

Analysis of Meter Sites with Tail Water and Surcharged Conditions

As indicated in Tables 3.8 and 3.9, 15 of the meter sites experienced surcharging and/or tail water conditions where the true peak inflow needs to be adjusted using the stage storage method. Provided below is a brief summary of each meter site and a determination if they have been determined to be RTS compliant.

012-PS

This station discharges into a city-owned gravity manhole in service area 014. A stage-storage analysis was not performed. A review of the wet weather hydrographs indicate that meter site 012-PS collected flow data from at least 3 other 1" events without tail water effects and the 1-year event with no tail water effects. The surcharged condition that occurred during the April 21, 2008 rain event resulted in a flat line velocity that prevented a stage-storage analysis to be performed. Therefore, a stage-storage analysis was not required to be performed to complete the RTK analysis for this meter site. It has been determined that this meter site is RTS compliant.

023-PS

This station discharges to a HRSD-owned gravity manhole. A stage-storage analysis was performed only on the Sept. 25, 2008 rain event since it was its only event to experience tail water and surcharged conditions. Surcharged conditions take the form of very spiky flows starting 2 days after the Sept. 25 rainfall event. It is unknown what causes this, but since 023-PS discharges to a gravity manhole, it is likely station operation conditions. Most importantly, the response to the storm on the first 2 days is definitely good enough to calculate true inflow rates and perform an RTK analysis, so it has been determined that this meter site is RTS compliant.

024-PS

This station discharges into a city-owned gravity manhole in HRSD service area 217. A stage-storage analysis was performed on all qualifying rain events that experienced tail water and surcharged conditions. This site has significant tail water and surcharged during all storms. While there is a plausible response to the April 21 storm, all other storm events indicate patterns which appear to be influenced by the pump start/stop levels. Overall, the Stage-Storage corrected data was still not sufficient for an RTK analysis of the flow meter data. This meter site has been determined to be non-RTS compliant.

026-PS

This station discharges into a city-owned gravity manhole in HRSD service area 223. A stage-storage analysis was performed on the August 10, August 15, and Sept. 25, 2008 rain events which are the only qualifying rain events for this meter site. Tail water and surcharged conditions during the August 10 and August 15 qualifying events could not be corrected by the stage-storage analysis, so we are unable to perform a wet weather analysis on these storms. Tail water effects on the Sept 25 event are comprised of spiky flows, so the RTK analysis could be completed. Since there is only the 1-year event, this site has been determined to be non-RTS compliant.

044-PS

This station discharges into a manifold city force main that connects to the HRSD force main system. A stage-storage analysis was performed only on the April 21, 2008 since it was its only event to experience tail water conditions. This is the only event that indicates tail water and surcharging conditions occur at this meter location. A true inflow rate has been calculated for this event. Therefore, the RTK analysis has been completed, and so it has been determined that this meter site is RTS compliant.

051-PS

This station discharges into a city-owned gravity manhole in HRSD service area 204. Stage-Storage analysis was not performed. Surcharging and tail water during the April 21 storm are minimal, but a brief period exhibits very spiky flows. This prevented stage-storage curves being created for RTK generation during this storm. Tail water effects during the Aug. 10 event consist of one short spike, therefore the RTK analysis was performed on this storm. Tail water during the Sep. 10 storm comprises a couple of short spikes; therefore RTK analysis can be performed on this storm. The result is that meter data from this meter site meets the minimum of three storm events to perform RTK analysis so it has been determined that this meter site is RTS compliant.

121-PS

This station connects to a HRSD force main. A stage-storage analysis was not performed. Tail water effects at this site comprise a single 15-minute spike in flow during the April 21 storm. The meter data is sufficient to perform the RTK analysis so it has been determined that this meter site is RTS compliant.

126-PS

This station discharges into a city-owned gravity manhole in service area 153. A stage-storage analysis was performed on its Sept. 5 and 25, 2008 rain events since these two rain events experience tail water and surcharged conditions. Tail water and surcharging conditions indicated for the Sep. 5 storm is caused by a short spike in flow approximately 2.5 days after the rainfall event. Since this is not related to the storm, the wet weather flows during this event are sufficient for analysis. Tail water effects during the Sept. 25 storm event comprise of spiky flows. These spikes are also present during the dry weather days preceding the storm event. It is believed that these spikes are a result of the physical system and not part of the storm response. However, the storm response is visible in the flow records. Therefore, a true inflow rate could be calculated, and the RTK analysis was completed for this Sept. 25 event. There are sufficient non-tail water impacted 1" events and the 1-year event, so it has been determined that this meter site is RTS compliant.

136-PS

This station connects to a HRSD force main. Stage-Storage analysis was performed only on the Sept. 25, 2008 rain event. The Sept. 25 storm event is the only event that indicates tail water and surcharging conditions occurred at this meter location. A true inflow rate has been calculated for this event. Therefore, the RTK analysis has been completed, and so it has been determined that this meter site is RTS compliant.

140-PS

This station connects to a HRSD force main. A stage-storage analysis was performed on the April 21 and Sept. 25, 2008 rain events since they were the only qualifying events that experienced tail water and surcharged conditions. Corrected flows at this location account for the tail water and surcharging for the April 21 and the Sep. 25, 2008 qualifying storms to calculate true inflow rates. Therefore, the RTK analysis has been completed, and so it has been determined that this meter site is RTS compliant.

143-PS

This station connects to a HRSD force main. A stage-storage analysis was performed only on the Sept. 25, 2008 rain event. The Sept. 25 storm event is the only event that indicates tail water conditions occur at this meter location. A true inflow rate has been calculated for this event. Therefore, the RTK analysis has been completed, and so it has been determined that this meter site is RTS compliant.

145-PS

This station connects to a HRSD force main. A stage-storage analysis was performed on the April 21, Sept 25, 2008 rain events since they were the only qualifying events that experienced tail water and

surcharged. Tail water and surcharged conditions during the April 21 and Sept. 25 events have been accurately corrected using the stage-storage method. True inflow rates have been calculated for these events. Therefore, the RTK analysis has been completed, and so it has been determined that the meter data from this meter site is RTS compliant.

146-PS

This station discharges into a city-owned gravity manhole in HRSD service area 219. Stage-Storage analysis was not performed. Tail water and surcharged conditions at this location are very short. This site has sufficient qualifying events that are not impacted by tail water so it has been determined that this meter site is RTS compliant.

154-PS

This pump station is a terminal pump station that discharges directly into the HRSD force main system. A stage-storage analysis was performed on the April 21, Sept. 5 and 25 qualifying rain events since they experienced tail water and surcharged conditions. Tail water and surcharged conditions that occurred during the April 21 storm cannot be corrected using the stage-storage method. This storm is considered unreliable. The Sept. 5 tail water effects are a spike in flow that happens 2 days after the event. This data is considered reliable and the wet weather parameters can still be calculated during this event. When the stage-storage method was applied to the Sept. 25 storm event, the tail water and surcharged conditions could not be corrected. This storm is considered unreliable. Because the required qualifying events could not be corrected, this has been determined to be non-RTS compliant.

159-PS

This pump station is a lift station that discharges into a gravity manhole within the HRSD service area 219. Stage-Storage analysis was performed on the August 15 and Sept. 25, 2008 rain events. Tailwater effects during the Aug. 15 storm show up twice. The first effect is believed to be a result of the storm. A second tail water spike occurs after the rainfall and is not considered to be part of the rainfall event. Its proximity to the rainfall event and a drop in average flow within 12 hours after the RDII response calls the data reliability during this storm into question. This storm is recommended to be not used as a qualifying event. The tail water effect around the Sept. 10 event happens a day after the rainfall and is a very short spike in flow. This spike is not believed to be related to wet weather flow and it does not have a significant impact on wet weather flow parameter generation, but this is not a qualifying event. The tail water that occurs during the Sep. 25 event is related to the storm event and the stage-storage method correctly adjusts the measured flow for tail water effects. True inflow rates have been calculated for this event. Therefore, the RTK analysis has been completed, and so it has been determined that the meter data from this meter site is RTS compliant.

Wet Weather Flow Analysis Conclusions

At the conclusion of the dry weather reliability analysis, it was determined that only 29 meter sites were considered RTS compliant. These results and the required re-associations of service areas are provided previously in Table 3.5. The wet weather reliability analysis resulted in meter site 047-PS in being non-RTS compliant leaving only 28 meter sites for continued analysis during wet weather events for RTS compliance. Site 047-PS shall be re-associated to another meter site in accordance to the RTS requirements which are provided in Section 2.

Additional analysis was conducted on 15 of the remaining 28 meter sites that experienced surcharging and/or tail water conditions where the true peak inflow needs to be calculated using the stage storage method for the three minimum qualifying rain events to determine if these meter sites are considered to be RTS compliant. This analysis provided above indicates that three of these 15 meter sites can not be

considered RTS compliant because a true inflow rate could not be calculated during the storm event using the stage-storage approach. These meter sites are 024-PS, 026-PS, and 154-PS.

The result of this is that Table 3.10 below shows final number of RTS compliant meter sites to be 24 of 104 total pump station service areas. In addition, this table identifies which meter site the non-RTS compliant meters have been re-associated to as a result of this wet weather flow analysis. Basin re-associations were conducted in accordance to the guidelines identified in Section 2 like all other previous basin associations.

Table 3.10: Final Service Area Associations

RTS-Compliant Wet Weather Flow Meter Locations (24 of 104 PSs)	Final Associated Service Areas
	¹ Re-Associated Basins during Dry Weather Analysis ² Re-Associated Basins during Wet Weather Analysis
010	None
012	006, 013, 014, 024² , 107
021	004, 005, 015¹ , 016, 017, 020, 101, 217
023	011, 022¹ , 026² , 027, 031, 032² , 036, 102, 113, 115, 206, 208, 219, 223, 224
035	002, 025, 034
037	001, 105, 106, 111, 114, 134
042	041, 043
044	033, 204, 225
048	007, 123, 203
051	028, 030² , 045, 046² , 047²
118	160, 161
121	003, 112, 119, 141
125	127, 131, 133
126	116, 117, 124, 137
136	None
140	None
142	132
143	100¹ , 103, 104, 122, 130¹ , 135¹ , 163¹ , 164, 209
145	None
146	154²
147	148, 165, 166, 167, 168
151	None
159	None
162	038, 098¹ , 144, 150, 152, 153, 170¹

Figure 3.3 below shows the meter associations graphically. Figure 3.4 shows the RTS-compliant monitored areas and Figure 3.5 shows both the compliant and non-compliant metered areas. Figure 3.6 shows the locations of the meters across the city.

Figure 3.3: Basin Associations

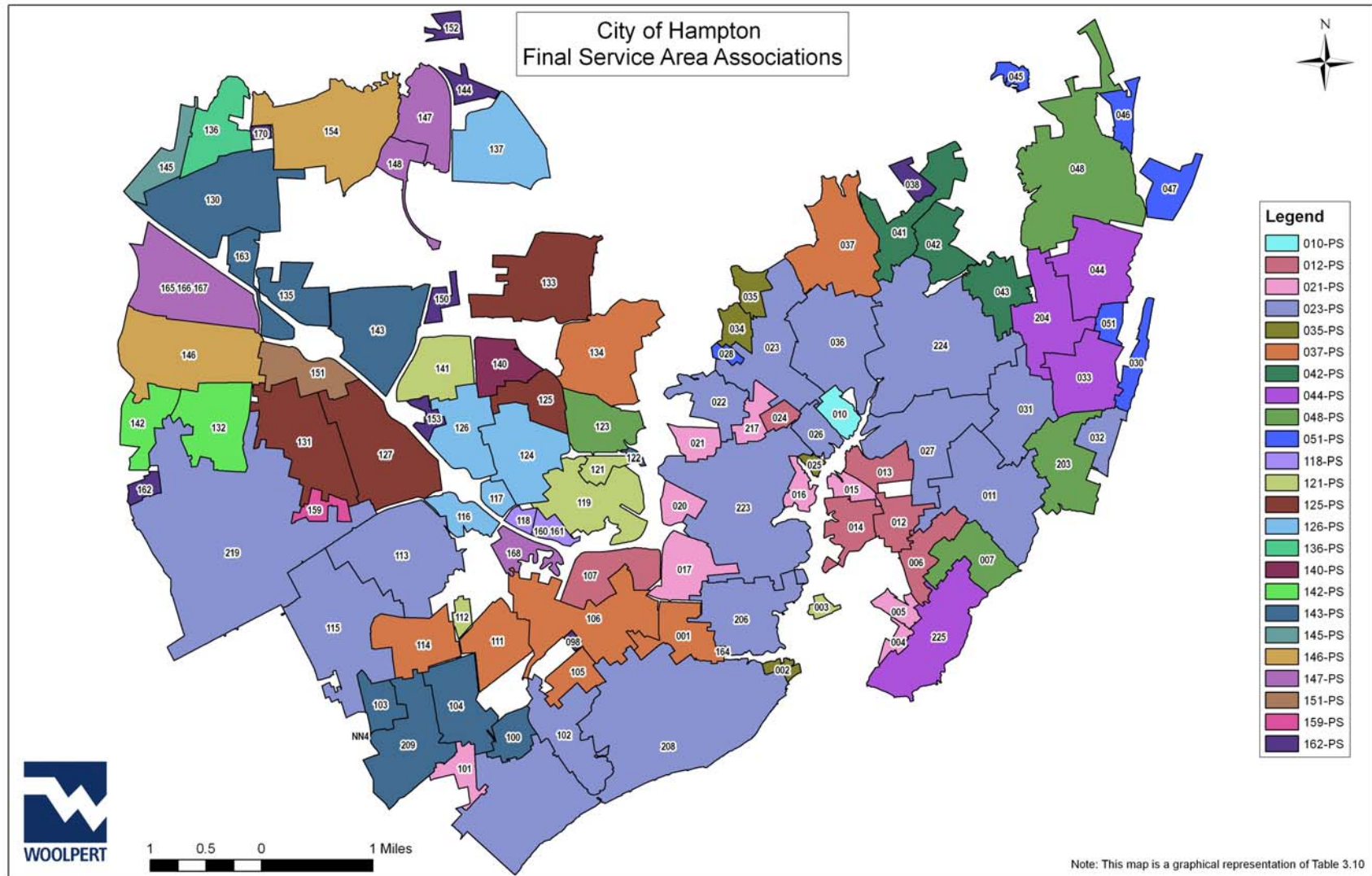


Figure 3.4: RTS-Compliant Monitored Areas

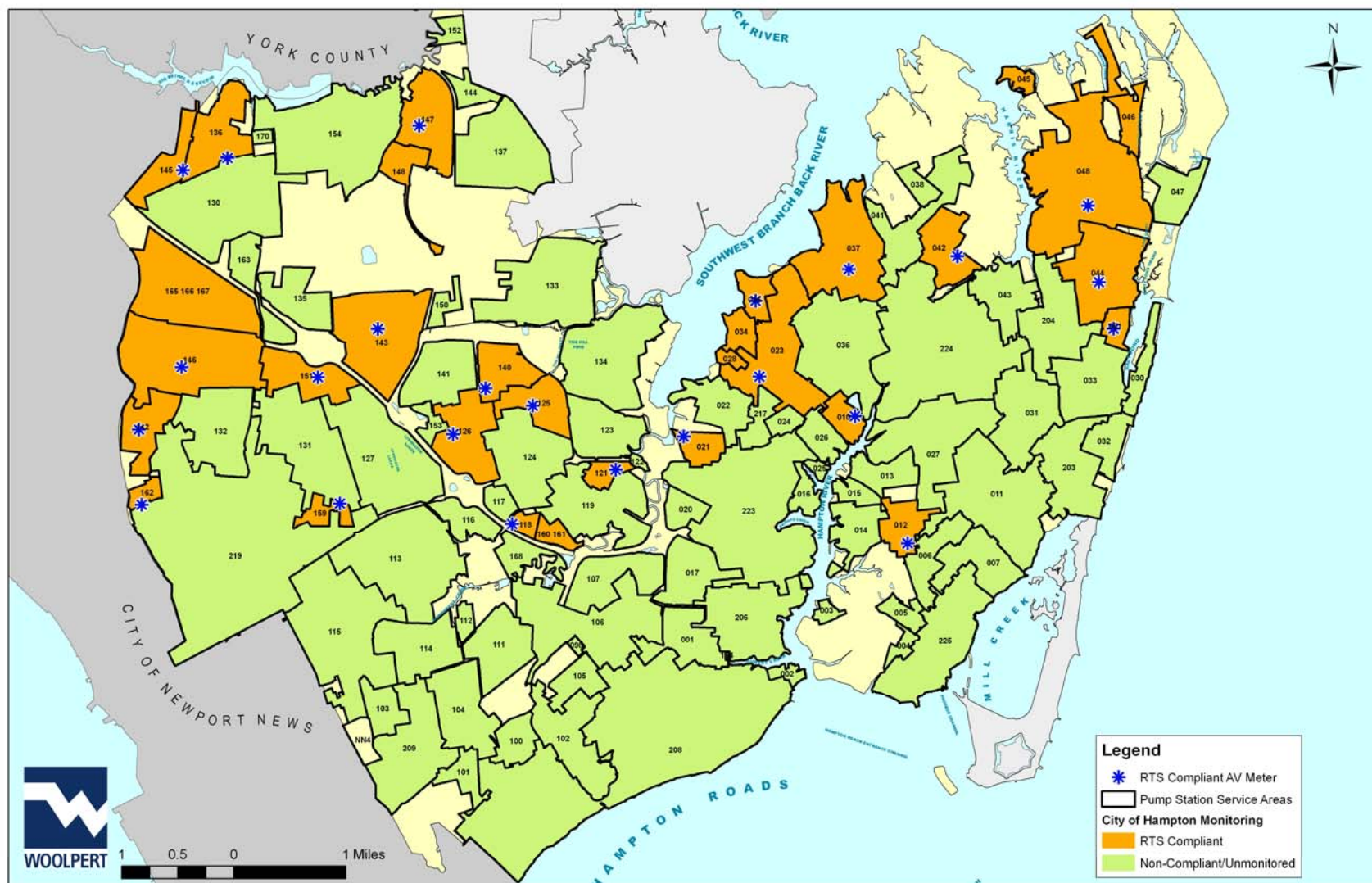


Figure 3.5: RTS-Compliant and Non-RTS-Compliant Monitored Areas

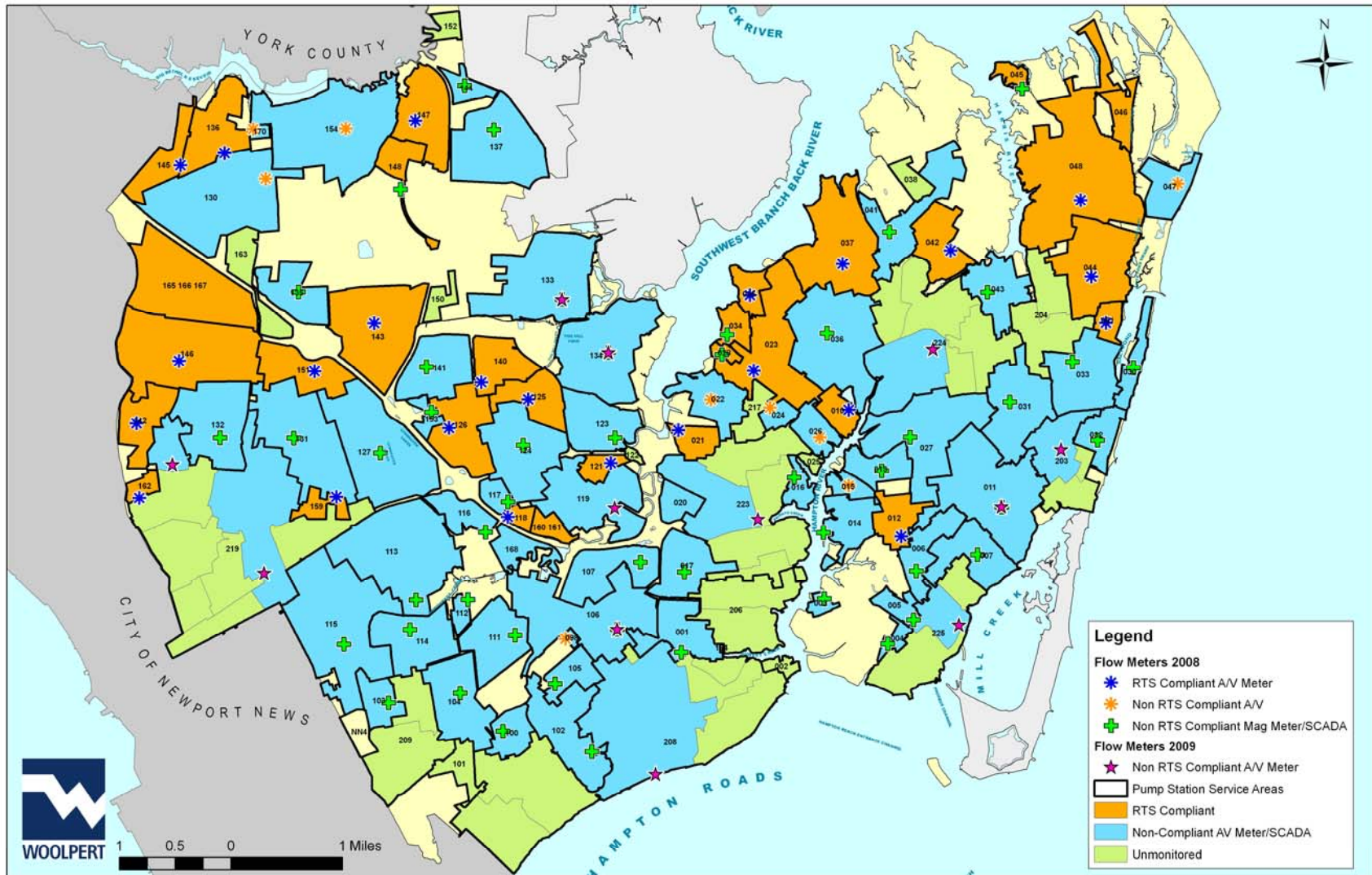
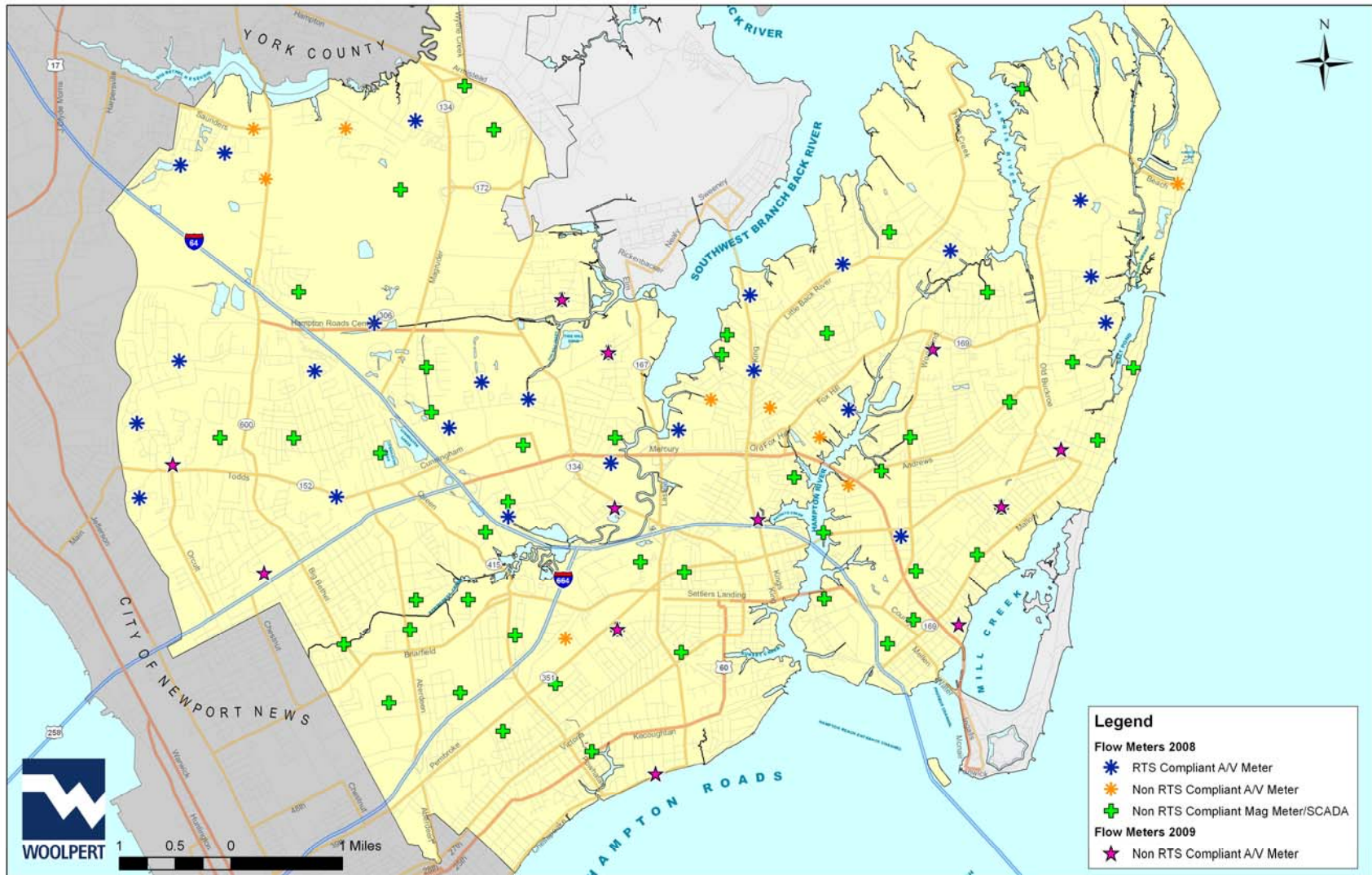


Figure 3.6: Flow Meter Locations with Compliance



Observed Flow Analysis

The Daily average, maximum, and minimum flows for all RTS-compliant meters are shown in Table 3.11. The Max and Min are the maximum and minimum recorded 15-minute flow rate for any given day. This table also shows the Peak Hour Flow during each storm event, as well as the Peak Hour Flow for the entire monitoring period. Yellow-highlighted storms indicate the 1-inch qualifying events and red-highlighted storms indicate the 1-year storm. Cells with a “XX” indicate unreliable data during a storm at that meter.

Table 3.11: Observed Wet Weather Flows at Monitoring Locations

Meter	Daily Average	15-min (cfs)		Peak Hourly Flow (cfs)						Monitoring Period
		Max	Min	4/21/08	8/10/08	8/15/08	9/5/08	9/10/08	9/25/08	
010-PS	0.025	0.202	0.004	0.076	0.031	0.030	0.030	0.034	0.030	0.179
012-PS	0.061	1.111	0.007	XX	0.114	0.139	0.123	0.121	0.164	1.006
021-PS	0.125	0.506	0.001	0.401	0.071	0.086	0.130	0.215	0.153	0.472
023-PS	0.264	1.096	0.075	0.936	0.563	0.893	0.503	0.429	0.819	0.936
035-PS	0.121	1.178	0.001	0.317	0.126	0.171	0.156	0.050	0.060	0.555
037-PS	0.102	0.395	0.001	0.329	0.278	0.307	0.120	0.110	0.152	0.366
042-PS	0.267	0.641	0.052	0.588	0.266	0.253	0.262	0.233	0.219	0.610
044-PS	0.056	0.725	0.001	0.292	0.129	0.142	0.134	0.122	0.142	0.602
048-PS	0.483	5.117	0.094	1.411	0.778	1.174	0.824	1.238	2.501	2.501
051-PS	0.057	0.665	0.013	XX	0.203	0.111	0.151	0.168	0.164	0.383
118-PS	0.220	1.057	0.040	0.480	0.471	0.734	0.380	0.394	0.441	1.000
121-PS	0.013	0.508	0.002	0.115	0.043	0.043	0.038	0.029	0.325	0.325
125-PS	0.041	0.236	0.012	0.070	0.089	0.069	0.083	0.079	0.215	0.215
126-PS	0.161	0.866	0.033	0.282	0.233	0.238	0.313	XX	0.592	0.592
136-PS	0.090	0.527	0.015	0.163	0.183	0.177	0.186	0.177	0.393	0.393
140-PS	0.103	1.718	0.006	0.403	0.212	0.191	0.196	0.565	0.460	1.287
142-PS	0.052	0.718	0.002	0.125	0.305	0.112	0.139	0.139	0.126	0.615
143-PS	0.052	1.719	0.002	0.108	0.132	0.148	0.202	0.168	0.613	1.657
145-PS	0.063	1.330	0.005	0.245	XX	0.160	0.185	0.171	1.286	1.286
146-PS	0.184	1.476	0.009	0.597	0.360	0.364	0.366	1.266	0.312	1.266
147-PS	0.145	1.195	0.006	0.312	0.239	0.311	0.229	0.311	0.283	0.590
151-PS	0.109	1.691	0.023	0.266	0.327	0.315	0.755	0.229	0.280	1.159
159-PS	0.022	0.201	0.001	0.064	0.028	XX	0.026	0.055	0.114	0.191
162-PS	0.016	0.113	0.001	0.020	0.032	0.036	0.042	0.038	0.093	0.093

Table 3.12 below indicates the RDII volume calculated for the 4-day window of each storm event (rainfall day plus the three following days). Each storm’s RDII volume is calculated by subtracting the average dry weather day’s diurnal hydrograph from the observed flows. This table is a compilation of values found in the statistics tables for each meter provided in Appendix G.

Table 3.12: RDII Volume Comparison

	4/21/2008	8/10/2008	8/15/2008	9/5/2008	9/10/2008	9/25/2008
010-PS	9162	1417	725	758	1030	9162
012-PS	XX	2722	5816	3256	3487	XX
021-PS	70405	915	995	4642	5482	70405
023-PS	89628	16193	17825	13151	4444	89628
035-PS	49632	47532	42236	8406	2774	49632
037-PS	46459	25061	34724	138	653	46459
042-PS	118303	11032	7785	4138	3856	118303
044-PS	54674	5140	6312	1412	1726	54674
048-PS	108238	28789	40318	9855	29029	108238
051-PS	XX	6888	6637	5574	3538	XX
118-PS	26450	32321	34911	5222	6299	26450
121-PS	17612	1390	1350	1632	817	17612
125-PS	7030	2580	446	8021	3411	7030
126-PS	16051	3653	4079	6162	23091	16051
136-PS	7462	6156	3918	3682	3931	7462
140-PS	13822	6652	6424	9204	8083	13822
142-PS	1672	5431	5039	4925	4193	1672
143-PS	1440	2487	4658	5912	6098	1440
145-PS	5679	XX	4748	4643	6044	5679
146-PS	49716	19665	12223	5650	11689	49716
147-PS	9913	2144	2623	737	6541	9913
151-PS	8061	9555	8353	6727	2080	8061
159-PS	6954	885	XX	943	1025	6954
162-PS	154	1081	1137	1734	1754	154

****Volumes are in cubic feet**

Due to fluctuations in groundwater levels at both seasonal and non-seasonal meter locations, some values of RDII volume can be slightly inflated or deflated because of higher or lower than normal DWI. When this is encountered during the development of RTK parameters, the shape of the RDII response should be matched even if the volume is slightly different. It is expected that the Regional Hydraulic Model's groundwater model will assist in the adjustment of DWI parameters so that an accurate storm RDII volume will be modeled. Unusual and non-storm-related events during the 4-day window have the potential to impact these reported volumes. During the development of the RTK parameters, any such flows during the 4-day window can be ignored by the engineer.

3.8 Hydrologic Model Calibration and Model Parameters

Dry weather parameters were calculated according to the procedures outlined in Sections 3.3 through 3.6. The wet weather RTK parameters were only developed for RTS-Compliant locations using the SSOAP program described in Section 3.7. The creation of the RTK parameters with SSOAP calibrates them to the metered flows in the monitored areas. The user can adjust the RTK parameters of up to three unit hydrographs that combine to simulate the RDII of actual storms. Once RTK parameters are created for storms that showed a wet weather response, the parameters are averaged for all storm events. As dictated by the Region, the Mike Urban program from DHI will be used to develop the collection system hydraulic models of each service area up to its point of connection to the HRSD system. The EPA-SWMM 5 program is embedded within Mike Urban and will facilitate the calibration of the wet weather hydrologic parameters for RDII response. EPA-SWMM 5 allows the use of the RTK method to calculate RDII, and the transfer of results from SWMM5 to Mike Urban's Collection System mode is streamlined. The hydrologic and hydraulic models must be calibrated for both dry- and wet-weather days to standards set in the RTS that are summarized below.

Dry Weather Flow (Baseflow)

For dry-weather flow, the following standards are set, in addition to matching general hydrograph shape. These standards are to be met for at least two dry-weather days.

- Predicted time of peaks and troughs will be within one hour of the observed flow
- Predicted peak flow rate will be within +/-10 percent of the observed flow data
- Predicted volume of flow over 24-hour will be within +/-10 percent of observed flow volume

Wet Weather Flow

For wet-weather flow (baseflow and RDII), the following standards are to be met, in addition to matching general hydrograph shape. These standards are based on generally accepted practices, and conform to the guidance published in the *Code of Practice for the Hydraulic Modeling of Sewer Systems (2002)* by the Wastewater Planning Users Group (WaPUG, 1998).

- Predicted time of peaks and troughs will be within one hour of the observed flow
- Predicted peak flow rates will be within -15 percent and +25 percent of the observed flow
- Predicted volume of wet-weather event flow will be within +20 percent and -10 percent of observed flow volume

- Predicted pump discharge pressure will be within +/-10 percent of observed pressure
- Predicted surcharge depth in manholes or other structures will be within +1.5 feet and -0.3 feet of the observed depth
- Predicted non-surcharged water surface elevations will be within +/-0.3 feet of the observed depth

Flow Parameter Database Development

One of the primary outcomes of this Flow Evaluation Report is the development of the Flow Parameter Database (FPD). This is a database containing flow parameters and diurnal hydrographs for all service areas. The “Catchment Flow Parameters” table contains parameters for each basin, while the “Diurnal Hydrographs” table contains the dimensionless diurnal hydrographs that were developed from monitored data. The “Catchment Flow Parameters” table contains the following information:

- 1.) Monitored status – Check-box field indicating whether the parameters were based on meter data (box checked) or were calculated through association (box left unchecked). The “Comments” field indicates whether a checked basin was with a RTS-Compliant meter or a non-RTS-compliant meter.
- 2.) Dry Weather Flow Parameters – Average Daily Flow, Base Sewage Flow, and Dry Weather Infiltration. Additional fields indicate the “Peak” and “Low” season BSF and DWI parameters for basins that were defined to have a seasonal variation.
- 3.) Dry Weather Diurnal Hydrograph – Reference field indicating which dimensionless pattern in the “Diurnal Hydrographs” table should be used in conjunction with the flow parameters to create the dry weather flow patterns for a basin.
- 4.) Wet Weather Flow Parameters – RTK parameters that were developed from analyzing the wet weather flows.
- 5.) Comments – This field indicates the RTS-Compliance status of monitored basins, as well as indicating other information that may be useful to CDM and HRSD modelers during RHM calibration.

A copy of the FPD that was delivered to CDM and HRSD on March 15, 2010 is included on the data disk in Appendix I. The Regional Hydraulic Model (RHM) will use these parameters for their initial simulations. Calibration procedures for the RHM will include discussions with the City about areas in need of further investigation or areas where differing flows needs to be reconciled. Basins that were not monitored are more likely to be adjusted. There are multiple entries for each of the large HRSD service areas. These are Catchments that were developed to support the Regional Hydraulic model. Each Catchment is a portion of the city’s gravity collection system within a HRSD basin and it is identified by the HRSD structure where flows in that area will be loaded in the Regional Hydraulic Model. The purpose of these Catchments is to simplify the loading of flows from multiple individual connections into one point. All parts of the HRSD service areas are included in a Catchment – there are no areas left out. A limited version of the “Catchment Flow Parameters” table showing the BSF, DWI, and RTK parameters for all basins is included as Table 3.13 below.

Table 3.13: Dry and Wet Weather Flow Parameters for All Basins

Service Area ID	ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
001-PS	34.074	21.181	12.893	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Mag Meter
002-PS	18.247	11.129	7.118	0.0032	1.75	1.00	0.0004	3.00	2.00	0.0025	10.00	5.00	Not Monitored	Not Applicable
003-PS	24.934	18.694	6.240	0.0069	1.50	1.60	0.0037	4.60	3.20	0.0089	7.20	5.00	Monitored - Non RTS Compliant	Mag Meter
004-PS	22.655	11.108	11.546	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Mag Meter
005-PS	16.815	6.403	10.413	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Mag Meter
006-PS	52.619	26.999	25.621	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - Non RTS Compliant	Mag Meter
007-PS	76.835	29.996	46.840	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Monitored - Non RTS Compliant	Mag Meter
010-PS	11.034	6.516	4.518	0.0015	0.90	1.50	0.002	3.50	2.75	0.002	8.75	5.25	Monitored - RTS Compliant	Open Channel Velocity Meter
011-PS	63.408	44.306	19.102	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
012-PS	27.297	15.987	11.311	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - RTS Compliant	Open Channel Velocity Meter
013-PS	24.583	12.407	12.176	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - Non RTS Compliant	Mag Meter
014-PS	63.492	30.867	32.625	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - Non RTS Compliant	Mag Meter
015-PS	16.874	4.484	12.391	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Open Channel Velocity Meter
016-PS	28.638	15.249	13.389	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Mag Meter
017-PS	32.937	9.780	23.156	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Mag Meter
020-PS	12.433	5.303	7.130	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - Non RTS Compliant	Open Channel Velocity Meter

Service Area ID	ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
021-PS	55.985	35.309	20.676	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Monitored - RTS Compliant	Open Channel Velocity Meter
022-PS	54.444	35.940	18.504	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
023-PS	118.463	79.983	38.480	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - RTS Compliant	Open Channel Velocity Meter
024-PS	41.448	19.190	22.258	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - Non RTS Compliant	Open Channel Velocity Meter
025-PS	7.018	2.932	4.085	0.0032	1.75	1.00	0.0004	3.00	2.00	0.0025	10.00	5.00	Not Monitored	Not Applicable
026-PS	23.325	14.678	8.647	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
027-PS	132.649	80.575	52.073	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
028-PS	9.264	3.266	5.999	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - RTS Compliant	Open Channel Velocity Meter
030-PS	26.852	13.610	13.242	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - Non RTS Compliant	Mag Meter
031-PS	125.714	88.450	37.265	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
032-PS	44.345	29.646	14.700	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
033-PS	61.508	44.686	16.822	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Monitored - Non RTS Compliant	Mag Meter
034-PS	18.439	4.874	13.565	0.0032	1.75	1.00	0.0004	3.00	2.00	0.0025	10.00	5.00	Monitored - RTS Compliant	Open Channel Velocity Meter
035-PS	54.284	29.293	24.991	0.0032	1.75	1.00	0.0004	3.00	2.00	0.0025	10.00	5.00	Monitored - RTS Compliant	Open Channel Velocity Meter
036-PS	162.708	109.396	53.312	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
037-PS	45.969	31.250	14.718	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - RTS Compliant	Open Channel Velocity Meter
038-PS	3.856	2.122	1.734	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Not Monitored	Not Applicable

Service Area ID	ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
041-PS	65.774	32.478	33.295	0.001	2.00	2.00	0.002	5.00	3.00	0.003	10.00	7.00	Monitored - Non RTS Compliant	Mag Meter
042-PS	119.864	58.954	60.910	0.001	2.00	2.00	0.002	5.00	3.00	0.003	10.00	7.00	Monitored - RTS Compliant	Open Channel Velocity Meter
043-PS	28.557	14.159	14.397	0.001	2.00	2.00	0.002	5.00	3.00	0.003	10.00	7.00	Monitored - Non RTS Compliant	Mag Meter
044-PS	25.215	18.803	6.412	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Monitored - RTS Compliant	Open Channel Velocity Meter
045-PS	9.327	2.567	6.760	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - RTS Compliant	Open Channel Velocity Meter
046-PS	0.080	0.080	0.000	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - RTS Compliant	Open Channel Velocity Meter
047-PS	32.050	13.559	18.492	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - Non RTS Compliant	Open Channel Velocity Meter
048-PS	216.841	102.453	114.388	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Monitored - RTS Compliant	Open Channel Velocity Meter
051-PS	25.502	14.970	10.533	0.0091	0.94	1.20	0.0027	4.80	3.00	0.0052	9.40	5.80	Monitored - RTS Compliant	Open Channel Velocity Meter
098-PS	1.694	0.960	0.734	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Monitored - Non RTS Compliant	Open Channel Velocity Meter
100-PS	30.106	14.902	15.204	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - Non RTS Compliant	Mag Meter
101-PS	35.377	10.417	24.960	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Not Monitored	Not Applicable
102-PS	111.855	70.277	41.578	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
103-PS	8.323	3.387	4.937	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - Non RTS Compliant	Mag Meter
104-PS	181.865	153.059	28.806	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - Non RTS Compliant	Mag Meter
105-PS	42.917	32.678	10.239	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Mag Meter
106-PS	168.582	91.833	76.749	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter

Service Area ID	ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
107-PS	105.208	74.624	30.584	0.0023	1.15	1.60	0.0013	4.20	2.60	0.0023	10.00	6.40	Monitored - Non RTS Compliant	Mag Meter
111-PS	47.917	28.256	19.661	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
112-PS	15.268	10.577	4.691	0.0069	1.50	1.60	0.0037	4.60	3.20	0.0089	7.20	5.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
113-PS	65.972	40.155	25.817	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
114-PS	36.874	27.655	9.219	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Mag Meter
115-PS	124.355	78.480	45.875	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Mag Meter
116-PS	9.094	3.168	5.925	0.002	1.25	1.50	0.0015	3.50	2.75	0.0018	8.50	6.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
117-PS	76.190	66.629	9.562	0.002	1.25	1.50	0.0015	3.50	2.75	0.0018	8.50	6.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
118-PS	98.499	66.124	32.376	0.0193	1.25	1.50	0.006	3.50	2.00	0.0065	7.50	5.00	Monitored - RTS Compliant	Open Channel Velocity Meter
119-PS	166.345	116.417	49.928	0.0069	1.50	1.60	0.0037	4.60	3.20	0.0089	7.20	5.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
121-PS	5.965	3.452	2.513	0.0069	1.50	1.60	0.0037	4.60	3.20	0.0089	7.20	5.00	Monitored - RTS Compliant	Open Channel Velocity Meter
122-PS	0.285	0.018	0.267	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Not Monitored	Not Applicable
123-PS	42.229	14.978	27.251	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Monitored - Non RTS Compliant	Mag Meter
124-PS	210.476	81.430	129.046	0.002	1.25	1.50	0.0015	3.50	2.75	0.0018	8.50	6.00	Monitored - Non RTS Compliant	Mag Meter
125-PS	18.538	9.023	9.515	0.0009	1.60	1.00	0.0006	3.75	2.75	0.0012	10.00	6.50	Monitored - RTS Compliant	Open Channel Velocity Meter
126-PS	72.186	35.203	36.984	0.002	1.25	1.50	0.0015	3.50	2.75	0.0018	8.50	6.00	Monitored - RTS Compliant	Open Channel Velocity Meter
127-PS	80.893	45.418	35.475	0.0009	1.60	1.00	0.0006	3.75	2.75	0.0012	10.00	6.50	Monitored - Non RTS Compliant	Mag Meter

Service Area ID	ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
130-PS	21.877	15.988	5.889	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
131-PS	40.357	17.091	23.266	0.0009	1.60	1.00	0.0006	3.75	2.75	0.0012	10.00	6.50	Monitored - Non RTS Compliant	Open Channel Velocity Meter
132-PS	62.113	52.204	9.909	0.0026	0.80	1.00	0.0009	4.00	2.40	0.0005	7.80	5.20	Monitored - Non RTS Compliant	Open Channel Velocity Meter
133-PS	54.031	43.862	10.169	0.0009	1.60	1.00	0.0006	3.75	2.75	0.0012	10.00	6.50	Monitored - Non RTS Compliant	Open Channel Velocity Meter
134-PS	70.083	43.004	27.080	0.0008	2.00	1.00	0.0007	4.00	3.00	0.0053	10.00	7.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
135-PS	36.098	20.125	15.973	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - Non RTS Compliant	Mag Meter
136-PS	40.299	30.484	9.814	0.001	1.17	1.00	0.0004	5.00	3.00	0.0017	10.00	6.33	Monitored - RTS Compliant	Open Channel Velocity Meter
137-PS	28.214	11.358	16.856	0.002	1.25	1.50	0.0015	3.50	2.75	0.0018	8.50	6.00	Monitored - Non RTS Compliant	Mag Meter
140-PS	46.170	20.009	26.160	0.0063	1.25	1.50	0.0019	3.50	2.00	0.0026	6.00	4.50	Monitored - RTS Compliant	Open Channel Velocity Meter
141-PS	90.148	79.789	10.359	0.0069	1.50	1.60	0.0037	4.60	3.20	0.0089	7.20	5.00	Monitored - Non RTS Compliant	Mag Meter
142-PS	23.344	18.915	4.428	0.0026	0.80	1.00	0.0009	4.00	2.40	0.0005	7.80	5.20	Monitored - RTS Compliant	Open Channel Velocity Meter
143-PS	23.476	14.410	9.066	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Monitored - RTS Compliant	Open Channel Velocity Meter
144-PS	14.137	12.810	1.327	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Not Monitored	Not Applicable
145-PS	28.040	21.218	6.822	0.0043	1.06	1.00	0.0023	3.50	2.00	0.0015	6.50	4.50	Monitored - RTS Compliant	Open Channel Velocity Meter
146-PS	82.652	60.450	22.202	0.0008	1.38	1.00	0.0011	4.00	2.50	0.0018	7.50	7.00	Monitored - RTS Compliant	Open Channel Velocity Meter
147-PS	64.841	49.760	15.081	0.0016	2.00	2.00	0.0004	4.00	2.00	0.0006	6.00	4.00	Monitored - RTS Compliant	Open Channel Velocity Meter
148-PS	7.765	0.145	7.620	0.0016	2.00	2.00	0.0004	4.00	2.00	0.0006	6.00	4.00	Monitored - RTS Compliant	Open Channel Velocity Meter

Service Area ID		ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
150-PS		7.817	6.907	0.910	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Not Monitored	Not Applicable
151-PS		48.676	34.242	14.434	0.0036	0.96	1.00	0.001	3.60	2.80	0.0016	5.80	4.80	Monitored - RTS Compliant	Open Channel Velocity Meter
152-PS		3.364	1.278	2.086	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Not Monitored	Not Applicable
153-PS		99.306	97.101	2.205	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Monitored - Non RTS Compliant	Mag Meter
154-PS		59.718	38.319	21.399	0.0008	1.38	1.00	0.0011	4.00	2.50	0.0018	7.50	7.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
159-PS		9.651	6.696	2.955	0.0041	0.83	1.67	0.004	3.67	2.33	0.0104	8.67	6.33	Monitored - RTS Compliant	Open Channel Velocity Meter
160-PS		11.926	11.926	0.000	0.0193	1.25	1.50	0.006	3.50	2.00	0.0065	7.50	5.00	Monitored - RTS Compliant	Open Channel Velocity Meter
162-PS		7.253	5.158	2.095	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Monitored - RTS Compliant	Open Channel Velocity Meter
163-PS		5.876	3.969	1.908	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Not Monitored	Not Applicable
164-PS		0.088	0.005	0.083	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Not Monitored	Not Applicable
165-PS		0.611	0.396	0.215	0.0016	2.00	2.00	0.0004	4.00	2.00	0.0006	6.00	4.00	Monitored - RTS Compliant	Open Channel Velocity Meter
168-PS		2.011	2.011	0.000	0.0016	2.00	2.00	0.0004	4.00	2.00	0.0006	6.00	4.00	Monitored - Non RTS Compliant	Open Channel Velocity Meter
170-PS		2.765	1.351	1.413	0.0011	0.50	1.50	0.0023	5.00	2.50	0.0035	10.00	5.50	Monitored - RTS Compliant	Open Channel Velocity Meter
203	100	81.005	36.500	44.505	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Not Monitored	Not Applicable
	119	40.105	6.405	33.700	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Not Monitored	Not Applicable
	130	102.442	40.974	61.468	0.0044	2.00	1.40	0.0026	4.60	3.00	0.0066	10.00	6.80	Monitored - Non RTS Compliant	Open Channel Velocity Meter
204	114	20.730	15.441	5.289	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Not Monitored	Not Applicable
	124	10.374	7.516	2.858	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Not Monitored	Not Applicable
206	102	49.292	31.390	17.902	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	384X	83.701	65.690	18.011	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable

Service Area ID		ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
208	100	66.111	38.929	27.182	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	107	96.550	57.629	38.921	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	119	246.202	131.410	114.791	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	135	59.113	37.891	21.222	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	157	21.568	13.848	7.720	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	162	15.707	9.606	6.101	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	187	7.765	5.920	1.845	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
209	116	15.207	9.449	5.758	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Not Monitored	Not Applicable
	122	11.333	4.925	6.408	0.0015	1.30	1.40	0.0003	3.40	2.40	0.0002	6.00	3.60	Not Monitored	Not Applicable
217	109	36.172	13.104	23.068	0.0063	1.50	1.00	0.0018	4.33	2.67	0.0089	9.00	6.33	Not Monitored	Not Applicable
219	103	24.368	15.749	8.619	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	109	14.731	12.303	2.428	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	114	94.319	80.809	13.510	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	132	50.586	30.993	19.592	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	139	215.828	178.564	37.265	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	159	31.111	18.665	12.446	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	163	275.873	130.790	145.082	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	172	62.822	52.146	10.676	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
223	100	42.643	33.657	8.985	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	103	48.492	32.323	16.168	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	121	91.539	51.511	40.028	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	122	59.120	48.744	10.376	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	140	46.136	32.434	13.702	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable

Service Area ID		ADF	BSF	DWI	R ₁	T ₁	K ₁	R ₂	T ₂	K ₂	R ₃	T ₃	K ₃	Monitored	Meter Type
224	100	29.522	19.223	10.299	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	101	55.577	27.334	28.242	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	110	51.855	37.553	14.302	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	124	54.894	34.760	20.135	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
	136	17.510	12.758	4.751	0.002	1.88	1.20	0.0026	4.60	2.80	0.0041	9.20	5.60	Not Monitored	Not Applicable
225	107	34.532	27.303	7.229	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Not Monitored	Not Applicable
	117	26.714	19.598	7.115	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Monitored - Non RTS Compliant	Open Channel Velocity Meter
	124	10.628	7.423	3.205	0.0009	1.48	1.17	0.002	3.83	2.67	0.0023	8.17	5.33	Not Monitored	Not Applicable

Appendix G contains graphs and plots showing the analysis of monitored basins. This analysis includes graphs of inflow hydrographs showing the metered storm response along with the simulated storm response using the single set of RTK parameters shown above. These graphs also include rainfall and lines indicating the Peak 10-Year Hourly Flow and the Peak Flow Threshold. The set of plots also includes level and velocity variation during the storm as a chronological plot and as scattergraphs. A scattergraph showing the entire monitoring period's data is included for reference. A tabular breakdown of the results of the storm simulation is also included in Appendix G. These tables show how the one set of RTK parameters (averaged from the multiple sets of individual storm parameters) compares when run against the individual storms. As was noted earlier, the list of dates and times of High Wet Well Alarms for all pump stations is included in Appendix H.

3.9 Peak Flow Estimation and Peak Flow Threshold Determination

10-Year Peak Hour Flow Projection on RTS Compliant Meter Sites

The RTS allows more than one method for projecting peak flows in the sewer system. The City of Hampton and Woolpert chose the RTK method of RDII simulation and the 10-year design storm for this analysis and for the SSES plan evaluation. Using the final RTS compliant meter sites identified in Table 3.10, the final RTK parameters for each of these meter sites were determined; they were entered into a SWMM model to simulate the response to a 10-year 24-hour design storm. For the City of Hampton, the DDF curves indicate a 5.53 inch rain event is expected to produce this design storm.

This 5.53 inch rainfall depth was applied to an SCS Type II distribution to model the storm. The SWMM model produced a hydrograph of the RDII derived from this storm using the RTK parameters developed previously. The peak flow was added to the peak dry weather flow to determine the 10-year peak flow estimate. The 10-year peak flow estimates at monitored locations are shown in Table 3.14 below.

Table 3.14: 10-Year Peak Flow Estimates

Meter	Sewered Area (Acres)	10-Year Peak Hour RDII Flow (GPM)	Peak DWF (GPM)	10-Year Peak Hour Flow (GPM)	10-Year Peak Hour Flow (GPD)	Upstream Piggyback Areas
010-PS	64	97.7	22.8	120.5	173519	
012-PS	104	184.6	50.5	235.2	338646	
021-PS	69	332.9	147.6	480.5	691901	
023-PS	465	707.1	184.6	891.7	1284012	028, 034, 035
035-PS	59	129.2	14.5	143.7	206902	
037-PS	251	157.2	104.7	261.9	377104	
042-PS	144	103.9	195.9	299.8	431675	
044-PS	239	224.7	48.1	272.8	392786	
048-PS	563	1511.8	337.2	1849.1	2662650	045, 046, 047
051-PS	37	301.0	42.3	343.3	494416	
118-PS	49	702.9	211.6	914.5	1316840	160, 161
121-PS	40	188.8	10.6	199.4	287074	
125-PS	134	98.2	30.2	128.4	184878	
126-PS	213	344.7	88.6	433.3	623995	
136-PS	156	135.1	68.3	203.4	292866	
140-PS	93	446.1	65.0	511.1	736026	
142-PS	143	378.1	46.6	424.7	611533	
143-PS	263	289.0	38.4	327.3	471362	
145-PS	104	417.3	70.7	487.9	702618	
146-PS	445	325.7	165.8	491.5	707705	165, 166, 167
147-PS	203	167.9	117.3	285.2	410692	148
151-PS	164	558.0	98.7	656.6	945511	
159-PS	40	161.3	22.6	183.8	264713	
162-PS	35	45.2	14.1	59.3	85438	

3.10 SSES Basin Determination Based on Peak Flow Threshold Analysis

SSES basins are designated when the projected 10-year peak hour flow (PHF) exceeds the peak flow threshold (PFT). Excessive peak flows are defined by the RTS as “Basins exceeding an actual peak flow of 775 gallons per day per equivalent residential unit (ERU) plus 3 times the commercial water consumption plus actual major industrial flows, where this peak flow is estimated to occur during rainfall conditions up to a ten-year, 24 hour rainfall recurrence interval.”

Peak Flow Threshold Calculations

Residential flows were estimated by multiplying the actual residential connections by 775 gallons per day. Data on the number of residential units per service area were obtained from GIS information provided by the City, review of aerial maps, internet research and windshield surveys. Each of the apartments, condominiums, townhomes, mobile homes and single family residential properties was counted as one residential connection. Actual commercial and industrial average annual daily flow data was obtained from Newport News Water Works.

The peak flow threshold for each service area was calculated from the estimated residential flow plus three times actual commercial and industrial water use to determine basins with excessive peak hour flows. The calculation described above represents the expected peak one-hour flow threshold for each basin.

SSES Basin Analysis for Associated Basins

Utilizing the PHF that was calculated in Table 3.14 for the metered sites using the RTK method; a unit PHF per inch diameter mile (IDM) for the metered site service area was calculated. Since the basins associated to the monitored basin are similar in types of land use, age, and pipe material type, this unit PHF/IDM value was then multiplied by the number of IDM of city sewer in each of the associated service areas identified in Table 3.10. This procedure calculates the PHF for each associated service area. To complete the SSES basin analysis, the associated service area PHF is compared to its service area's PFT. If the estimated PHF exceeded the PFT, then the associated service area qualifies as an SSES basin.

Table 3.15 located at the end of this section, identifies all the metered service areas, associated service areas, their respective PHF and PFT flows, and a determination if the service area is identified as an SSES basin. The results of this analysis indicate that 77 SSES basins have been identified by the PFT method. This number includes Newport News stations and HRSD basins within the city limits. Note that some pump stations listed in this table do not have a service area or are already included in a combined basin as noted previously in the report.

Table 3.15: Peak Flow Analysis for SSES Basin Determination

Service Area	Monitored/Associated/ Excluded	Projected 10 yr. 24 hr PHF (gpd)	Peak Flow Thresh. (gpd)	Exceeds Peak Flow Threshold
001-PS	Associated with 037-PS	330,341	482,505	No
002-PS	Associated with 035-PS	58,919	50,829	Yes
003-PS	Associated with 121-PS	216,699	55,187	Yes
004-PS	Associated with 021-PS	311,190	70,183	Yes
005-PS	Associated with 021-PS	639,256	98,476	Yes
006-PS	Associated with 012-PS	403,826	431,147	No
007-PS	Associated with 048-PS	1,807,995	377,301	Yes
010-PS	Monitored	173,519	99,975	Yes
011-PS	Associated with 023-PS	1,566,610	1,223,601	Yes

Service Area	Monitored/Associated/ Excluded	Projected 10 yr. 24 hr PHF (gpd)	Peak Flow Thresh. (gpd)	Exceeds Peak Flow Threshold
012-PS	Monitored	338,646	374,511	No
013-PS	Associated with 012-PS	244,021	139,305	Yes
014-PS	Associated with 012-PS	354,726	304,465	Yes
015-PS	Associated with 021-PS	427,168	41,075	Yes
016-PS	Associated with 021-PS	467,089	179,546	Yes
017-PS	Associated with 021-PS	2,290,216	303,329	Yes
018-PS	Excluded	NA	NA	Excluded
019-PS	Excluded	NA	NA	Excluded
020-PS	Associated with 021-PS	247,462	80,051	Yes
021-PS	Monitored	691,901	436,943	Yes
022-PS	Associated with 023-PS	485,841	382,386	Yes
023-PS	Monitored	1,010,336	782,218	Yes
024-PS	Associated with 012-PS	84,262	70,729	Yes
025-PS	Associated with 035-PS	33,867	11,625	Yes
026-PS	Associated with 023-PS	243,939	187,550	Yes
027-PS	Associated with 023-PS	1,323,753	1,026,520	Yes
028-PS	Associated with 051-PS	281,543	20,267	Yes
030-PS	Associated with 051-PS	1,343,799	236,009	Yes
031-PS	Associated with 023-PS	739,887	607,281	Yes
032-PS	Associated with 023-PS	316,943	398,444	No
033-PS	Associated with 044-PS	494,007	431,314	Yes
034-PS	Associated with 035-PS	251,412	102,438	Yes
035-PS	Monitored	206,902	293,844	No
036-PS	Associated with 023-PS	1,104,050	902,257	Yes
037-PS	Monitored	377,104	484,550	No
038-PS	Associated with 162-PS	70,719	12,406	Yes
041-PS	Associated with 042-PS	400,735	316,206	Yes
042-PS	Monitored	431,675	312,325	Yes
043-PS	Associated with 042-PS	400,472	350,300	Yes
044-PS	Monitored	392,786	365,292	Yes
045-PS	Associated with 051-PS	317,278	26,350	Yes
046-PS	Excluded	NA	NA	Excluded
047-PS	Associated with 051-PS	1,600,819	143,045	Yes
048-PS	Monitored	2,513,704	389,516	Yes
051-PS	Monitored	494,416	178,554	Yes
098-PS	Associated with 162-PS	29,941	4,078	Yes
100-PS	Associated with 143-PS	349,108	110,950	Yes
101-PS	Associated with 021-PS	866,213	125,073	Yes
102-PS	Associated with 023-PS	807,895	728,553	Yes
103-PS	Associated with 143-PS	121,834	17,243	Yes
104-PS	Associated with 143-PS	491,752	322,708	Yes
105-PS	Associated with 037-PS	129,876	221,728	No
106-PS	Associated with 037-PS	663,543	836,171	No
107-PS	Associated with 012-PS	393,459	524,944	No
111-PS	Associated with 037-PS	316,809	325,571	No

Service Area	Monitored/Associated/ Excluded	Projected 10 yr. 24 hr PHF (gpd)	Peak Flow Thresh. (gpd)	Exceeds Peak Flow Threshold
112-PS	Associated with 121-PS	207,273	58,125	Yes
113-PS	Associated with 023-PS	1,384,066	1,056,396	Yes
114-PS	Associated with 037-PS	236,185	567,248	No
115-PS	Associated with 023-PS	1,589,844	1,388,645	Yes
116-PS	Associated with 126-PS	419,683	252,851	Yes
117-PS	Associated with 126-PS	72,659	891,781	No
118-PS	Excluded	NA	NA	Excluded
119-PS	Associated with 121-PS	1,043,410	251,380	Yes
121-PS	Monitored	287,074	66,679	Yes
122-PS	Excluded	NA	NA	Excluded
123-PS	Associated with 048-PS	2,184,461	366,958	Yes
124-PS	Associated with 126-PS	1,530,674	1,311,901	Yes
125-PS	Monitored	184,878	192,495	No
126-PS	Monitored	623,995	580,511	Yes
127-PS	Associated with 125-PS	827,558	1,071,868	No
130-PS	Associated with 143-PS	341,477	102,357	Yes
131-PS	Associated with 125-PS	940,401	871,676	Yes
132-PS	Associated with 142-PS	621,556	556,651	Yes
133-PS	Associated with 125-PS	755,632	952,884	No
134-PS	Associated with 037-PS	395,266	681,406	No
135-PS	Associated with 143-PS	360,212	175,472	Yes
136-PS	Monitored	292,866	380,676	No
137-PS	Associated with 126-PS	494,976	261,009	Yes
140-PS	Monitored	736,026	478,708	Yes
141-PS	Associated with 121-PS	1,183,082	1,245,671	No
142-PS	Monitored	611,533	242,361	Yes
143-PS	Monitored	471,362	277,328	Yes
144-PS	Associated with 162-PS	54,122	180,483	No
145-PS	Monitored	702,618	368,728	Yes
146-PS	Monitored	705,880	835,352	No
147-PS	Monitored	235,058	784,512	No
148-PS	Associated with 147-PS	175,634	18,047	Yes
150-PS	Associated with 162-PS	37,138	61,779	No
151-PS	Monitored	945,511	685,364	Yes
152-PS	Associated with 162-PS	85,078	5,089	Yes
153-PS	Associated with 162-PS	15,036	434,801	No
154-PS	Associated with 146-PS	541,749	457,355	Yes
159-PS	Monitored	264,713	61,225	Yes
160-PS	Excluded	NA	NA	Excluded
161-PS	Excluded	NA	NA	Excluded
162-PS	Monitored	85,438	55,304	Yes
163-PS	Associated with 143-PS	99,174	58,956	Yes
164-PS	Associated with 143-PS	4,301	1,426	Yes
165-PS	Excluded	NA	NA	Excluded
166-PS	Excluded	NA	NA	Excluded

Service Area	Monitored/Associated/ Excluded	Projected 10 yr. 24 hr PHF (gpd)	Peak Flow Thresh. (gpd)	Exceeds Peak Flow Threshold
167-PS	Excluded	NA	NA	Excluded
168-PS	Excluded	NA	NA	Excluded
170-PS	Associated with 162-PS	57,647	21,700	Yes
203-PS/Bay Shore	Associated with 048-PS	2,974,687	786,656	Yes
204-PS/Bloxoms Corner	Associated with 044-PS	497,861	402,085	Yes
206-PS/Bridge Street	Associated with 023-PS	941,274	1,044,058	No
208-PS/Claremont Avenue	Associated with 023-PS	4,846,536	4,037,573	Yes
209-PS/Copeland Park	Associated with 143-PS	660,055	171,685	Yes
217-PS/Langley Circle	Associated with 021-PS	782,790	558,374	Yes
219-PS/Newmarket	Associated with 023-PS	3,391,857	3,561,736	No
223-PS/Washington St	Associated with 023-PS	1,779,446	1,961,056	No
224-PS/Woodland Road	Associated with 023-PS	1,922,860	1,681,338	Yes
225-PS/Willard Ave	Associated with 044-PS	1,002,025	959,899	Yes
NN 002-PS	Excluded	NA	NA	Yes**
NN 004-PS	Excluded	NA	NA	Yes**
				**Newport News Report
		70,264,900	49,474,492	
SSES Total				77
Excluded Total				11
Non SSES Total				26

4.0 FINDINGS AND CONCLUSIONS

4.1 Discussions of Findings

The results of the flow monitoring study reflect the nature of the city of Hampton. The older, low-lying areas tend to have more pronounced groundwater infiltration while newer, higher elevation areas tend to have lesser infiltration issues. Since it is a coastal city, the groundwater table is closer to the surface leading to an even larger infiltration effect. The city of Hampton is nearly completely built out, but development is expected in certain service areas. This report will assist with the classification and distribution of flows across the city.

4.2 Electronic Media Data

Listed below is a discussion and summary of the information contained in each folder on the electronic media submitted on the data disk included in Appendix I. The disk contains a PDF copy of this document in addition to folders containing data for the Appendices of this report.

Appendix A – Large Maps: This folder contains nine figures from the body of the report in high resolution. These images and PDF files are sized to be printed on 11 x 17 paper.

Appendix B – DDF Curves for Rainfall Events: This folder contains Rainfall Depth-Duration-Frequency curves for the city of Hampton with each rainfall event measured at each rain gauge superimposed on the curves. This allows for identification of the return period of each rain gauge's response for each storm.

Appendix C – Gravity Flow Meter Installation Reports: The PDF document in this folder contains the open channel area-velocity meter installation sheets for all of the 33 sites chosen for RTS compliance as shown in Figure 2.2.

Appendix D – Gravity Flow Meter Maintenance Reports: This folder contains all weekly Meter Issue Pages that identified sites that needed to be visited. It also contains the records of all City of Hampton crew visits to maintain the meters for both routine maintenance and in response to the issues noted in the Meter Issue Page. The folder also contains the records of all times that Woolpert crews visited each meter and what was performed during that visit.

Appendix E – Gravity Flow Data and Dry Weather Diurnal Flow Patterns: This folder contains the 5-minute meter data for all locations. It also contains a PDF document with all of the dry weather diurnal hydrographs developed for Area-Velocity metered locations. This folder also contains a copy of the Flow Parameter Database that was provided to HRSB and CDM on March 15, 2010.

Appendix F – Stage-Storage Analysis Graphs and Corrected Inflow Hydrographs: This folder contains all of the stage-storage curves developed for the stations identified in section 3.7 that required stage-storage analysis to correct for tail water effects. This appendix also contains hydrographs showing the comparison of observed versus corrected flows.

Appendix G – Wet Weather Hydrographs and Simulation Statistics: This folder contains one file per meter and each file contains the following items:

- 1) Inflow Hydrographs for each of the 6 storms during the 4-day window. These hydrographs show observed/adjusted inflows, simulated inflow, rainfall, peak flow threshold, and 10-year peak hour flow.

-
- 2) Level and Velocity variation over time for each of the 6 storms. For sites that are affected by tail water conditions, this set of plots vividly shows these effects as a decreasing or flat velocity with increasing levels.
 - 3) Scattergraphs of metered data during each of the 6 storms. This also assists with identifying tail water impacted data.
 - 4) Scattergraph of data for the entire monitoring period.
 - 5) 15-minute hydrograph of the entire monitoring period. This is useful for identifying seasonal trends.
 - 6) Calibration Statistics showing the calculated storm response parameters. It also shows the goodness of fit of the simulated response to each storm to the measured response. These statistics were initially requested by HRSD.

Appendix H – SCADA High Wet Well Alarm Records: This folder contains the record of high wet well alarms at all alarm-capable pump stations in the city during each of the 6 storm events.

4.3 SSES Basin Results from Peak Flow Analysis

Based upon the results of the peak flow analysis in Section 3.10, 77 pump station service areas were identified as having excessive peak flow during a projected ten-year storm. Additional criteria contained in the RTS could result in additional SSES basins being identified in the SSES plan. The changes documented previously in this report will significantly change all previous SSES plans and addendums on file with DEQ. The City of Hampton will begin to prepare an Amended SSES plan, based on the results of this Amended FER, to DEQ as soon as practical.

4.4 Future Hydrologic Model Calibration Efforts

The Mike Urban models that will be developed for compliance with the consent order will be calibrated as described in Section 3.8. Future calibration efforts will be made in conjunction with HRSD's Regional Hydraulic Model and will be addressed through discussions at the monthly Model Users' Group meetings and coordination meetings between HRSD and the City.

Comments from an HRSD memo to the City of Hampton, dated 1/26/2010, have been incorporated into this revised report. Results from this analysis performed in support of the Regional Hydraulic Model are included in Section 3 and Appendix G of this revised report.

Appendix A

Large Maps

Appendix B

DDF Curves for Rainfall Events

Appendix C

Gravity Flow Meter Installation Reports

Appendix D

Gravity Flow Meter Maintenance Reports

This printed document contains one of each document representing the meter maintenance log.

- 1) Sample Meter Issue Page – Meters were analyzed on a weekly basis at minimum. This form was created and transmitted weekly to City of Hampton meter maintenance crews to identify sites needing attention.**
- 2) Sample of City of Hampton Work Order Log – City crews kept track of time spent visiting meters in response to the Meter Issue Pages. These records are generated from the city’s GBA Work Order Management System.**
- 3) Sample Woolpert Meter Visit Log – Woolpert crews kept track of visits to meters and actions performed in a database. This sample page is the record of all visits to a specific meter.**

For the complete set of each of these types of documents, please see Appendix D on the Data Disk.

Appendix E

Gravity Flow Data
&
Dry Weather Diurnal Flow Patterns

Sample Area-Velocity Open Channel Flow Meter Data

Meter 151-PS

<i>Time</i>	<i>Level (inch)</i>	<i>Velocity (ft/s)</i>	<i>Flow (cfs)</i>
9/20/2008 15:00	2.34	1.15	0.125
9/20/2008 15:05	2.36	1.12	0.124
9/20/2008 15:10	2.44	1.12	0.13
9/20/2008 15:15	2.49	1.15	0.137
9/20/2008 15:20	2.33	1.23	0.133
9/20/2008 15:25	2.39	1.1	0.124
9/20/2008 15:30	2.47	1.13	0.133
9/20/2008 15:35	2.29	1.04	0.11
9/20/2008 15:40	2.29	1.06	0.112
9/20/2008 15:45	2.4	1.19	0.135
9/20/2008 15:50	2.52	1.07	0.13
9/20/2008 15:55	2.56	1.07	0.133
9/20/2008 16:00	2.52	1.12	0.136
9/20/2008 16:05	2.55	1.18	0.146
9/20/2008 16:10	2.35	1.07	0.117
9/20/2008 16:15	2.36	1.02	0.113
9/20/2008 16:20	2.46	1.02	0.12
9/20/2008 16:25	2.5	1.12	0.134
9/20/2008 16:30	2.51	1.16	0.14
9/20/2008 16:35	2.49	1.12	0.134
9/20/2008 16:40	2.45	1.05	0.122
9/20/2008 16:45	2.44	1.08	0.125
9/20/2008 16:50	2.47	1.18	0.139
9/20/2008 16:55	2.35	1.14	0.125
9/20/2008 17:00	2.37	1.1	0.122
9/20/2008 17:05	2.35	1.07	0.117
9/20/2008 17:10	2.4	1.08	0.122
9/20/2008 17:15	2.43	1.07	0.123
9/20/2008 17:20	2.32	1.02	0.11
9/20/2008 17:25	2.59	1.19	0.15
9/20/2008 17:30	2.5	1.15	0.138
9/20/2008 17:35	2.58	1.19	0.149
9/20/2008 17:40	2.48	1.1	0.13
9/20/2008 17:45	2.45	1.09	0.127
9/20/2008 17:50	2.42	1.07	0.123
9/20/2008 17:55	2.56	1.23	0.153
9/20/2008 18:00	2.72	1.23	0.166

Please see Appendix E on the Data Disk for the complete data set of all meters.

This printed document contains one sample plot of the dry weather diurnal patterns generated from the Area-Velocity open channel gravity flow meters.

For the complete set of diurnal patterns, please see Appendix E on the Data Disk.

Appendix F

Stage-Storage Analysis Graphs & Corrected Inflow Hydrographs

Appendix G

Wet Weather Hydrographs and Simulation Statistics

This printed document contains one sample set of plots and statistics generated from a metered location. This set includes the following types of information:

- 1) Inflow Hydrographs for each of the 6 storms during the 4-day window. These hydrographs show observed/adjusted inflows, simulated inflow, rainfall, peak flow threshold, and 10-year peak hour flow.**
- 2) Level and Velocity variation during the storm. For sites that are affected by tail water conditions, this set of plots shows these effects.**
- 3) Scattergraphs of metered data during each storm.**
- 4) Scattergraph of data for the entire monitoring period.**
- 5) 15-minute hydrograph of the entire monitoring period. This is useful for identifying seasonal trends.**
- 6) Calibration Statistics showing the calculated storm response parameters. It also shows the goodness of fit of the simulated response to each storm to the measured response. These statistics were initially requested by HRSD.**

For the complete set of wet weather graphs and statistics for each meter, please see Appendix G on the Data Disk.

Appendix H

SCADA High Wet Well Alarm Records

**Sample page of High Wet Well Alarm Log during the 6 storm events.
See Appendix H on the Data Disk for the complete set.**

Date	Time	Pump Station	Station Code	Pump Station ID
21-Apr	11:31:26	003-PS	1	001-PS
21-Apr	13:39:31	140-PS	2	002-PS
21-Apr	13:42:56	140-PS	3	003-PS
21-Apr	14:06:06	140-PS	9	011-PS
21-Apr	21:45:25	025-PS	10	012-PS
21-Apr	21:49:42	025-PS	11	013-PS
22-Apr	0:31:29	025-PS	14	016-PS
22-Apr	4:09:02	100-PS	21	025-PS
22-Apr	4:52:50	001-PS	22	026-PS
22-Apr	4:59:12	001-PS	23	027-PS
22-Apr	4:59:12	100-PS	24	030-PS
22-Apr	6:35:45	141-PS	26	032-PS
22-Apr	6:37:41	141-PS	40	100-PS
22-Apr	6:39:33	141-PS	42	102-PS
22-Apr	6:47:25	134-PS	44	104-PS
22-Apr	6:52:23	124-PS	50	113-PS
22-Apr	6:53:02	124-PS	56	122-PS
22-Apr	6:53:16	124-PS	58	124-PS
22-Apr	7:37:57	153-PS	60	126-PS
22-Apr	9:00:15	154-PS	61	127-PS
22-Apr	9:29:17	145-PS	62	130-PS
22-Apr	10:04:08	153-PS	63	131-PS
22-Apr	10:14:56	124-PS	64	132-PS
22-Apr	10:14:56	134-PS	65	133-PS
22-Apr	10:14:56	141-PS	66	134-PS
22-Apr	10:14:56	145-PS	67	135-PS
22-Apr	10:14:56	154-PS	68	136-PS
22-Apr	10:15:32	011-PS	70	140-PS
22-Apr	10:28:19	141-PS	71	141-PS
22-Apr	10:28:26	141-PS	72	142-PS
22-Apr	11:14:22	130-PS	75	145-PS
22-Apr	11:45:46	130-PS	76	146-PS
22-Apr	11:45:46	141-PS	80	152-PS
22-Apr	11:45:46	011-PS	81	153-PS
22-Apr	11:48:35	011-PS	82	154-PS
22-Apr	11:58:02	002-PS	97	164-PS
22-Apr	12:03:05	153-PS	119	119-PS
22-Apr	12:26:33	145-PS		
22-Apr	13:24:54	153-PS		
22-Apr	13:26:48	002-PS		
22-Apr	13:33:50	001-PS		
22-Apr	13:49:30	011-PS		

Appendix I

Data Disk